S. HRG. 98-233

THE EFFECTS OF THE PROPOSED TIDAL HYDRO-ELECTRIC PROJECT IN THE BAY OF FUNDY

HEARING

BEFORE THE

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS UNITED STATES SENATE

NINETY-EIGHTH CONGRESS

FIRST SESSION

JULY 25, 1983

AUGUSTA, MAINE

Printed for the use of the Committee on Environment and Public Works

U.S. GOVERNMENT PRINTING OFFICE
24-222 O WASHINGTON: 1983

S321-24

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MONDAY, JULY 25, 1983

U.S. SENATE,
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS,
Augusta, Maine.

The committee met at 9:30 a.m. in the Appropriations Committee room, State House, Augusta, Maine, Hon. George J. Mitchell presiding.

OPENING STATEMENT OF HON. GEORGE J. MITCHELL, U.S. SENATOR FROM THE STATE OF MAINE

Senator MITCHELL. Good morning, ladies and gentlemen. I want to begin by welcoming everyone, especially the witnesses who will testify here today, and thank them for the time and effort they have taken to prepare for today's hearing. Each witness brings a particular interest and expertise to the subject, and it is my hope that their testimony will contribute to our understanding of the effects—environmental and otherwise—in New England of the proposed Canadian tidal power projects.

I emphasize at the outset that this hearing is intended to provide an opportunity to hear and consider all perspectives on this issue. It will hopefully enable all of us to clarify and compile the information that exists on this subject, thereby diminishing speculation and allaying any public concern.

Tidal power could be an important alternative source of long-term, nonpolluting, competitively priced energy. For Maine and other New England States, these are important considerations. Oil, the fuel with which most of us heat our homes and run our industries, is increasingly costly and subject to external action. Citizens of our State are especially aware oil is a fossil fuel which, when burned, emits sulfur dioxide and contributes to acid rain and other pollution problems. Maine reduces these emissions through considerable effort and expense; therefore, a new and cleaner energy source deserves thoughtful review by all Maine citizens.

Concerns have been raised, however, that tidal power projects in the Bay of Fundy could have adverse effects on the New England coast all the way along the coast of Maine and as far south as Massachusetts and Boston Harbor. Some studies suggest that the Minas Basin project, which is being actively considered for construction in Nova Scotia, would change tidal range along the coast of Maine by nearly 1 foot. This could have serious implications for our coastal environment,

would increase storm damage to coastal roads and buildings, and alter fisheries and shellfish production. These and many other possible effects command our attention here in Maine where so many of our citizens live and work along the coast, where thousands of visitors enjoy our State—and especially our coast—each year and where commercial fishing contributes $300 million annually to the State's economy.

Ordinarily, at these hearings, we run through the day with a break for lunch but because the U.S. Senate will be in session this afternoon with votes commencing at 5:30. I will have to leave at 1 o'clock. And since no other Senator was able to be present, we'll change a little bit and run right through from now until 1 o'clock so that we can hear all of the witnesses.

The hearing will, however, adjourn precisely at 1. Therefore, I would ask each witness to summarize their statements and be prepared to make their main points in no more than 10 minutes. All written statements will be inserted into the record in full, and the record will remain open for 30 days from today to permit additional information to be inserted.

I want to welcome our first witness, Governor Brennan. And in so doing, I want to recognize the attention he has given to this issue. The Governor has closely followed the progress of the proposed tidal power projects and is very much aware of their possible implications, both positive and negative here in Maine. As a representative of the people of Maine, Governor, we welcome you here today.

STATEMENT OF HON. JOSEPH E. BRENNAN, GOVERNOR, STATE OF MAINE

Governor BRENNAN. Thank you very much, Senator Mitchell. Ladies and gentlemen, present with me is Dick Berringer, the director of our planning office and John Carey, the director of our energy office who likewise will be available for questions.

I do want to thank you for this opportunity to address the committee on the development of tidal power in the Bay of Fundy on its potential effects on the coast of Maine and New England, and our request for analysis of these effects by the U.S. Army Corps of Engineers.

We appreciate the committee holding this hearing in Maine, and we are especially grateful to you. Senator Mitchell, for your efforts on behalf of the State which we both serve.

I would like to take this opportunity to thank all of the participants in this hearing.

George Baker's presence representing Fundy Tidal Power Corp. is just one more demonstration of the fine relationships that we enjoy with our Canadian neighbors. I wish also to thank Colonel Sciple and the New England Division of the U.S. Army Corps of Engineers for their energetic assistance to the State of Maine in this and in other matters. At this time I would like to commend the U.S. Army Corps of Engineers for the excellent relationship that the State of Maine has enjoyed with the corps over the years. I make that point because too often too many of us spend much of our time criticizing some of the

governmental agencies. When you have some that do a good job, that enjoy a good relationship, I think it's appropriate to commend them, and that is the relationship we in Maine have enjoyed with the U.S. Army Corps.

While you are here, I hope our out-of-State guests take a chance to look at Maine and observe some of its natural beauty.

I especially commend the coast to you which is now at its finest. Once you have experienced the Maine coast, you will more fully appreciate our great desire to safeguard it.

Our coast is essential to the commerce of this State. It supports a substantial fishing industry, it is central to our striving tourism industry, and the 20,000 people who make their living in that industry.

The public and private investment in Maine coastal property totals hundreds of millions indeed if not billions of dollars.

But even more important, our coast is also an irreplaceable part of the quality of life that we enjoy in this State. Its natural beauty and diversity, its rockbound shores, sand beaches, marshes, wetlands, its countless off-shore islands, abundant fish and wildlife, including endangered species like the bald eagle, and the generous opportunities for recreation which it provides are truly priceless, and we do not take its future lightly.

Maine has led the Nation in enacting tough environment laws to curb pollution. We have established innovative programs like our coastal conveyance fund to respond to oil spills, and we have mounted substantial efforts to restore productive fisheries and to reduce clam flat pollution.

We are also investing a great deal in the future of our coast. In 1981, Maine voters approved two bond issues, one for $10 million to build commercial fish piers in seven coastal communities and another for $28 million for a cargo port in Searsport and a ship repair facility in Portland.

My administration has a firm commitment to protect Maine's coast from any threats that would spoil its value or diminish the benefits which it affords Maine's people and Maine's wildlife.

At the same time, we are fully cognizant of the fact that Maine is among the States most heavily dependent on foreign oil.

This dependence is politically unwise and economically unhealthy. And it casts a shadow over the State's future well-being. That is why I have long supported the development of renewable energy resources to meet Maine's energy needs and especially to reduce our dependence on foreign oil.

Maine has a long history of importing electrical power from Canada.

Major agreements have been reached of late with the Provinces of Quebec and New Brunswick for long-term energy exchanges and electrical power purchases. Since these accords benefit both the New England States and the eastern Provinces of Canada, we are likewise interested in power exchanges from Nova Scotia.

In addition to the mutual benefits of these historic accords, consideration of the Fundy tidal project is consistent with our comprehensive State energy policy, which states that:

The long-term policy of the State of Maine shall be to encourage energy conservation and diversification and the use of indigenous and renewable resources so that the State can become more nearly self-sufficient.

In the interim, the State should encourage the development and use of resources, consistent with this goal, which are the least harmful to the environment, which stimulate economic development, and which promote security of supply and are available at the lowest possible cost. . . .

We believe that tidal power offers exciting opportunities for the development of substantial new sources of secure energy for Maine.

My administration has strongly supported the investigation of tidal power potential in the Gulf of Maine and in the Bay of Fundy. We have encouraged the Corps of Engineers in their studies of Cobscook Bay and continue to urge completion of their environmental impact assessments.

While we are optimistic that tidal power will one day live up to its promise, it remains too early to commit ourselves to any of the projects now under consideration until a number of complex issues are resolved. At the same time our energy dependence demands that we not dismiss out of hand any project with the protential to reduce our energy costs and increase our energy security.

Our friends in Nova Scotia understand that we cannot endorse any project if the costs, environmental or economic, are too great. In the case of the Minas Basin project, those costs are yet to be fully determined. Tidal power on the scale of the Minas Basin represents a new, untried technology. We have no experience to determine how well it will generate power or to show what will be the full environmental impact along the Maine coast and along the entire New England coast.

The Maine Public Utilities Commission will carefully examine any proposal by a Maine utility to finance construction of the Minas Basin project. We shall, of course, be interested in purchasing Fundy tidal power only if it is competitively priced.

But we are also concerned that the environmental effects of the Minas Basin project will be acceptable to Maine. We urge that this issue be dealt with openly and resolved at the earliest possible time to avoid possible conflicts with our good neighbors.

Last winter, I directed the State planning office to investigate the potential effects of Fundy tidal power development on the Maine coast, both positive and negative. Today, you will hear the details of a preliminary report from the Bigelow Laboratory for Ocean Sciences in Boothbay. The Bigelow lab report is an important step forward. It represents the first examination of the Minas Basin proposal by anyone from the perspective of Maine and from the perspective of the United States.

It is not intended as a comprehensive assessment or as a final evaluation of the proposal. The review of the report by our State agencies is not completed.

Its value is simply as a first step, an overview, identifying the most significant, likely effects of the Minas Basin project on the Maine coast and recommending priorities for further research by U.S. and Canadian authorities.

Today, however, we can say with certainty that there is urgent need to update the ocean engineering studies upon which all the impact assessments are now based.

You will hear this morning from Dr. David Greenberg of the Bedford Institute. We have the utmost respect for him and the highest

regard for his work on the complex dynamics of the Gulf of Maine. The pioneering work he began almost 10 years ago must now be brought up to date under state-of-the-art computer modeling techniques.

The U.S. Army Corps of Engineers is ready and best equipped to undertake such an investigation on this side of the Canadian border.

I urge the Congress to authorize and appropriate the funds necessary to begin these studies at the earliest possible time.

Apart from clarifying the effects of the Fundy tidal power project, these studies will be valuable in helping our marine and geological scientists understand the complex dynamics of the Gulf of Maine, of the migratory patterns of our fisheries, and the critical effects of the recent subsidence along our eastern coast.

We also strongly encourage Mr. Baker and the Fundy Tidal Power Corp. to continue their investigation of the economics of the Minas Basin project. And, if we may as friends, we recommend further research into small-scale projects and alternative sites as well.

We are certain that our long-term mutual interest will be best served by the most economically and environmentally acceptable combination of all of these possibilities.

We sincerely congratulate the province of Nova Scotia on its experimental initiative at Annapolis Royal. We are watching this test project with great interest and are hoping earnestly for its success. We look to it for preliminary answers to many of our questions.

Energy is but one of the many concerns which we share with our Canadian neighbors. We have a long history of outstanding relations with our neighboring provinces and with the Federal Government in Ottawa. We know that this relationship will continue. We look forward to an ongoing dialog with our friends from the eastern provinces and the pursuit of mutual goals that will assure a safe and secure source of energy for all our future interests.

You will hear further this morning from a number of Maine officials, including the commissioner of marine resources, Spencer Apollonio. I urge early expedient congressional action on our request and swift completion of the corps' studies. It is sound public policy to take these steps at this time.

On another matter, I wish to bring to the attention of the committee our grave concern for the problems of soil erosion in the St. John River Valley of Aroostock County. I am leaving with you some written testimony on the important demonstration project proposed by the Corps of Engineers to reverse this intolerable situation.

We wholeheartedly endorse and support the corps' approach, and we shall be most grateful if the committee sees fit to authorize this project at an early time.

Again, we appreciate the hearing being held in Maine and giving us the opportunity to speak to this committee today. Thank you very much.

Senator MITCHELL. Thank you very much, Governor. The erosion project on the St. John River Valley, which you mentioned, let me say that Senator Cohen and I last week introduced legislation to authorize the corps to proceed with this project over the next 3 fiscal years. It is my hope that this legislation will be accepted when the Water Re-

sources Subcommittee meets in the near future, and that we'll be able to hopefully work together to obtain final approval by the Senate and the necessary appropriation. I agree with you on the importance of that project.[1] I thank you also for your very thoughtful testimony here this morning.

I appreciate Mr. Carey and Mr. Berringer for being here with you. Thank you very much.

I call the next witness: Mr. George Baker, the executive vice president of the Tidal Power Corp.

Mr. Baker, we welcome you to Maine. We share a great deal in common with Nova Scotia, geography, history, and outlook and interest, and we are very happy to have you here. We want you to know, Mr. Baker, it is like this all the time in Maine, the weather.

Mr. BAKER. Thank you very much, Mr. Chairman. Do you wish me to put my qualifications on the record?

Senator MITCHELL. I don't think that is necessary, Mr. Baker. I think you are well known here for your background and interest, and I would prefer that you devote your time to a discussion of the issues here.

STATEMENT OF G. C. BAKER, EXECUTIVE VICE PRESIDENT, TIDAL POWER CORP.

Mr. BAKER. Thank you, Mr. Chairman. My first words then will have to be to say that my corporation welcomes your interest of tidal power and appreciates this opportunity to participate in your hearings this morning.

I would like to cover three topics in my submission. First is a general and very brief description of the tidal resources. The second is a discussion of the nature of a committee decision and the events that might lead up to it, and the third is a discussion of the environmental effects on the United States if the tidal power project is built.

The resource has been studied intermittently since 1966, and technical investigations have now defined the possibility of producing significant quantities of energy at prices which will be somewhat lower than the price of generation from hydrocarbon fuels. There are two sites for which economic prospects have been determined. One of them we have been calling A–8, and it involves damming the mouth of the Cumberland Basin. That site would produce about 3,400 gigowatt-hours of energy each year.

The other site involves damming part of the Minas Basin, and depending on the number of turbines installed, it would produce between 11,600 and 14,000 gigowatt-hours per year.

In addition, a third site in Shepody Bay has not so far been shown to be economically developed in isolation. But might eventually be felt to benefit to work in combination with the other two sites.

The upper Fundy tidal resource therefore has an ultimate economically developable potential of somewhat more than 20,000 gigowatt-hours per year.

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[1] A statement from Governor Brennan on the St. John River project may be found at p. 57.

We have found that the simplest types of tidal plants are most economical. They do not produce continuous output but generate discret pulses of energy with a duration of about 6 or 6½ hours per time. Intermittent energy from a tidal plant would be useful in reducing utility fuel bills, and that is the only value we have assigned to that energy in our studies. That value is more than sufficient to support development costs, but I would like to suggest that, in addition, if a purchasing utility has access to river hydro, it can convert the intermittent tidal energy into firm energy available on demand. The same thing would be true if the utility had pump storage facilities.

The intermittent nature of the tidal energy does, however, lead to one marketing restriction, and it is quite an important one. The proportion of tidal energy supplied to any one system can only be a small fraction of the total energy used by that system, and that means that the amount of tidal energy absorbable with advantage by the Maritime Provinces is quite a large—is quite a small proportion of the overall of any of these feasible schemes

Senator MITCHELL. Mr. Baker, as I told you earlier, I read your report. As I understand your study, it is based upon the consumption by the Maritime Provinces of 10 percent of the output of the Minas Basin Dam, with 90 percent for export to the United States market, is that correct?

Mr. BAKER. That is correct. And the figure would be about 40-percent retained, 60-percent exported of the smaller of those two schemes.

Senator MITCHELL. Of the 90 percent that you propose to export on the larger proposal to the United States, you have broken it down in equal portions between the New England and the New York markets, is that correct?

Mr. BAKER. That was purely an emotional breakdown for the basis of economic analysis. The actual distribution might be the same or different.

Senator MITCHELL. That was my question. That was not based upon any marketing analysis of the needs of the two regions, I gather, but simply you made just an arbitrary allocation between the two?

Mr. BAKER. We did the analysis. But the analysis would indicate the advantage of sending all the energy to New England, but we thought that since that would set the highest value on the economic benefits due to tidal power, we shouldn't take that.

Senator MITCHELL. In that respect, you adopted a more conservative approach?

Mr. BAKER. Right. The point I want to make is development is implicitly dependent on export markets. None of those sites will be developed in this century anyway just to supply the Maritime Provinces.

Our latest studies conducted with the cooperation of the New York Power Pool and New England Power Pool indicate there will probably be, in the period 1995 to 2015, a large part to cover fuel dependency in these markets. And we have thought that tidal power could displace a relatively small portion of that hydrocarbon fuel.

Tidal plants, like other hydro developments, would have very long lives and the cost output would be independent of inflation, or prac-

tically independent of inflation, as soon as the construction period is over. The power would be pollution free, but it would have the environmental impacts. Most of the impact is on the aquatic environment. That is a very brief outline of the nature and extent of the resource.

I would like to talk now for a moment or two about commitment decision. The studies done to date have been of the nature of feasibility studies. They don't indicate the best way necessary to build a plant, and they have been taken in isolation from the environmental studies. They don't supply a lot of the information needed to make a rational commitment decision. That information would be extremely expensive to get and before one could spend the $50 or $100 million required to gain that information, they would be prudent to try to get some assurance on some other vital matters of concern, and those other vital matters include the availability of markets, the availability of export permits, and the availability of project financing.

If some degree of assurance were obtained on those three points, the way would be open for a precommitment program covering definitive design and environmental assessment and conditional agreements regarding finance, transmission, and sales. After all, if that work had been done, it would be possible to make a logical decision whether or not to commit to construction of a tidal project. And we are talking about perhaps 3 years of concentrated effort, perhaps more.

Senator MITCHELL. Mr. Baker, you talk about meeting the three requirements, markets, export permits, and financing. Of course, the financing, as you make clear in your study, would be based upon the availability of markets. You have stated that exports would account for 90 percent of the production and would require financing from U.S. purchasers. Only at that point, I gather, would you get into the environmental impact?

Let me tell you what I am leading to. What concern me is that there may be a tendency to develop the economic benefits of a project to the point where concern for environmental impact is seen as obstructing an otherwise viable project, depending upon the sequence in which you study these things. I would hope that to the extent you can do so, you can, in the course of this precommitment study that you talked about, over the next 3 years factor in all the benefits and disadvantage in a relatively simultaneous fashion so that you don't get a project that seems to have an inevitability about it, and then it appears to be sort of a negative last-ditch effort to stop in on environmentally grounds. Do you follow the point?

Mr. BAKER. I understand your concern, Mr. Chairman. Let me say that the points within which I said we would like some assurance, we can only get assurance to the extent of letters of comfort or something like that, and that would be a relatively short-term search if the conditions are feasible. One, of course, could not tie down markets before one had done all the other work—the design, the environmental assessment, and had environmental approval of construction of the project. So the preliminary things would be matters on which you could get letters of comfort or something of that nature.

The main thrust would be on definitive design, environmental assessment, and those things would have to go hand in hand. There could be

no commitment to a project under the laws pertaining in Canada until the environmental assessment had been done. And before it could be done, indeed it would be necessary to have guidelines issued specifying the content and the things the assessment wishes to address. And even after that, one could only hope to get approval in principle. There would still be environmental control over various aspects of construction.

Senator MITCHELL. I assume that Canadian law contemplates an evaluation of the environmental impact within Canada, and that is the ordinary circumstance. Our concern, as you know, from the environmental effects standpoint is the potential adverse impact in this country and specifically in New England.

Can you tell me at this point the extent to which you would contemplate, as part of your environmental assessment, the effects outside of Canada, that is, along the Maine coast? Do you anticipate that will be an integral part of your environmental assessment? If you do, can you at this stage give us some idea of the relative significance of those effects in the decisionmaking process?

Mr. BAKER. Yes, Mr. Chairman. It would be necessary under the sort of assessment that this project would get if it were totally a Canadian project to look at the impact of the United States as well as the impacts of Canada.

The second point is that you can't really divide these impacts into a U.S. package and a Canadian package. We share a joint fishery. The effects on your coastlines will not be too different than the effects on our own coastlines.

And the third point and from a purely practical point of view, having nothing to do with international law or anything else, this project can't be a one-country project if we hope to sell it in the second country. We would never get financing for the project unless we had a drastic U.S. concern and could tell the people who were being asked to put out capital, yes, it was clean and green.

Now, the final point is—perhaps not the final point but an important point—that we would depend for getting that energy to market on transmission routes which would have to be supplied by the jurisdiction or have to be authorized, OK, approved by the U.S. jurisdiction involved. Couldn't have transmission, couldn't sell the energy. There would be no protest. The energy would be coming down. The energy could be attached by the process of law if anybody had a suit against them.

So from the purely practical point of view, the thing has got to be looked at not on the basis of U.S. impacts and Canadian impacts, but on the basis of total impact. And while I am on that theme, I would like to say, Mr. Chairman, that it would be the submission of my corporation that the wisest, most efficient way to go at the thing would be to set up a joint agency responsible both to Canada and the United States for the environmental regulation and control of a tidal power project if one ever comes to fruition or the expectation that it will be one.

Senator MITCHELL. You contemplate this, Mr. Baker, at the Federal levels in both countries?

Mr. BAKER. Let me preface that by saying that my corporation has just had some experience with one project in Canada where both the

Federal and provincial levels were involved. And I presume that there will be environmental concerns relevant to both Federal and State levels in the United States, and it is beyond the competence of my corporation to say how a joint agency should be formed. But I think as a general principle, we can say that whatever agencies are formed, they should be responsive to all the concerns whether they are Federal or State, and I daresay that protocol would mean that you would have to make the arrangements through Federal tax.

Senator MITCHELL. Mr. Baker, it would be helpful to me and the committee were we made more precisely aware of the manner in which this other project was handled. Would you, following the hearing, submit in writing some description of how it has been done in this other project? It may or may not be something that we could utilize and adapt here.

Mr. BAKER. I would be very pleased to, Mr. Chairman. (See p. 73.)

Senator MITCHELL. Your earlier answer indicated to me that you believed that the States affected in this country and our Federal Government, will be able to exercise a great deal of influence over the development of this project because it requires their financial participation and their purchase of the power.

And I gather that what you are saying is that you recognize that, and you are going to work closely to evaluate, assess, and take into consideration any potential environmental effects in Maine because you are going to be asking Maine or other New England or American States for financing. You are going to ask them to buy the power and ask them for permission to construct transmission lines?

Mr. BAKER. That's right. I think, of the three, the financing and transmission lines are the vital things.

Senator MITCHELL. Right.

Mr. BAKER. Insofar as the need to take into account all the U.S. impacts, could I say one other thing: We can, to a certain extent, mitigate impacts by the definitive design of the project. That is a general statement. It has nothing to do with tidal power. But in the case of the tidal powerplant, some of the impacts are undefined. We can make it through the design of a plant. When it comes to changes in tidal range along the New England coast, it is doubtful that we can provide much mitigation and indeed, it may turn out to be that it is not possible to make any mitigation if we want to build a plant.

Under such circumstances, rather than walking away from the project, and saying, well, it is no good, we can't do it, the option not to be open and, in the general case, is open to provide compensation. And it is this submission of my corporation that in the case of damages, if they're consequential and they suffered as a result of increasing the tidal range, they would have to be compensated. This would be the cost of the project, and it would be a part of the cost of energy. So that the cost of the damage would, in the final analysis, be paid by the people who got the benefits.

Senator MITCHELL. Do you have in mind any mechanism for the assessment and required payment of the compensation in a case like that?

Mr. BAKER. I have some ideas, but I am afraid I would have to describe them as half faith. I think that whatever compensation was

paid would have to be paid on the effect of assessed actual damages rather than forecast damage ahead of the advantage.

Second, if I were speaking for U.S. jurisdiction, I would want some precommitment to pay damages up to at least an assessed level, and I think I would leave it to the lawyers to say from that point on how the thing would be organized.

Senator MITCHELL. That will be sure to produce confusion and delay, Mr. Baker.

Mr. BAKER. There is only one other thing, Mr. Chairman, in my intended submission that I think I should mention. A good deal of work has been done on environmental impacts by Canadian authorities. The Fundy's studies committee on account of that has been a coordinating body, and I would welcome anything the United States would care to do to help in these studies. I would like to draw a distinction between the fundamental research necessary to make environmental assessment possible and the actual assessment.

Now, in the fundamental research, it would be far better to identify the missing spokes in the wheel and supply those spokes than it would be to reinvent the wheel. Therefore, this is a plea for close cooperation with Canadian environmental authorities. Thank you very much, Mr. Chairman.

Senator MITCHELL. Well, thank you very much, Mr. Baker, that is a very good statement. I have a number of questions for you. In your update 1982 which is the most recent analysis of this project, you cite a benefit to cost ratio of approximately 2.4. Do I understand that ratio, however, does not reflect the cost of environmental damage or mitigation; that it is based just on the factors that went into this report which did not include mitigation of environmental difficulties, is that correct?

Mr. BAKER. That is correct.

Senator MITCHELL. So depending upon the extent to which there would be a cost to mitigate the environmental damage, the benefit cost ratio would be reduced by some degree impossible to tell at this time?

Mr. BAKER. That is correct. On the other hand, that is not the upper bound of the thing either. It might be possible to make more efficient design than the one postulated in that study. So that I guess it is a question of fact if after including the environmental costs of things it still looks to be worth doing, you do it. If it doesn't, you walk away from it.

Senator MITCHELL. Well, indeed in the 5 years between your first report and this one, your benefit cost ratio increased significantly and the same could be true in the years that intervene between now and the time you have to make a final decision?

Mr. BAKER. Yes, I agree, Mr. Chairman.

Senator MITCHELL. You might get some adverse environmental impact, some beneficial impact from other factors, and your benefit cost ratio may increase rather than decrease.

Now, when you make your environmental assessment, you have already indicated your willingness to cooperate with American agencies, and I hope very much that you will. I also hope that we'll be able to follow through on that so you can take into account to the

fullest extent possible and include in your data base information available from the studies that are ongoing. You have the Bigelow study here in this State, as you know, and we hope to make that available to you and have you take that into account.

You mentioned earlier the importance of American financing, that is, American investors, primarily the utilities who will be the purchasers of the power. Can you tell us if you know, Mr. Baker, whether those American investors will be subject to Canada's Foreign Investment Review Act?

Mr. BAKER. I don't believe so, Mr. Chairman. The question would hinge on the narrower question whether the investment would be by way of equity or contributing capital or simply capital put up loaned as long-term debt to the scheme.

The Foreign Investment Review Act, according to my understanding, only relates to situations where a large proportion of the ownership is to be other than Canadian. And depending on what financing scenario we are taking for this scheme, it would not be absolutely necessary to have U.S. equity participation to the extent that it will attract the unfavorable notice of that bureaucratic body.

Senator MITCHELL. This is an important consideration for us, Mr. Baker, because as you know, Canada's Foreign Investment Review Act makes it possible for the Canadian Government to substantially limit the control which outside investors, in this case, the American investor, can have on the Canadian enterprise. That would be a significant matter, I am certain, for the utilities because some would obviously be citizens of this State and may want to encourage operational methods that would minimize the adverse effects on this State.

Mr. BAKER. Yes.

Senator MITCHELL. I am going to ask our staff on the committee to look into that that, and I'll share whatever conclusions we reach with you and with the affected American utilities because I think that is a matter of some significance. And I gather what you were saying earlier, and I don't want to misstate this, was that it is clear, reading update 1982, that since you plan to export 90 percent of the power, this project, as presently conceived, could not be built without American financing and American purchase of a substantial portion of the power?

Mr. BAKER. I would delete American financing from the statement. I think it could be built without American financing. It could not be built without American purchase of the power, and it would be most prudent from the point of view of anybody that is an entrepreneur in the thing to have American financing because if your revenue is denominated in U.S. dollars, you'll stop gambling with exchange rates if you have your debt also denominated in U.S. dollars so it is preferable to have American financing.

Senator MITCHELL. Have you reached a stage where you have contemplated the specific nature of the construction of the dam? This would be a very substantial project. How wide an area would the dam cover from point to point on the Minas Basin?

Mr. BAKER. Five miles, sir.

Senator MITCHELL. And how high would the dam be?

Mr. BAKER. It would necessarily have to have a free board of 26 feet or so above highest high water, and that would give it a depth in round figures of 150 feet perhaps, top to bottom.

Senator MITCHELL. As I understand your report, taking inflation into account, the projected cost over the period of construction, which is about 10 years, would be approximately $23 billion; is that correct?

Mr. BAKER. If inflation were 10 percent per year compounding over that period, that is correct.

Senator MITCHELL. And in constant dollars as it is, 1981 dollars unadjusted for inflation, could you have something in excess of $16 billion?

Mr. BAKER. Yes.

Senator MITCHELL. That is a very massive construction project which would be built in Canada. Do you have any thoughts on participation by American firms and American workers in view of the fact that the overwhelming majority of the power is to be exported to the United States?

Mr. BAKER. No particular studies have been made on socioeconomic matters since 1976. I will state that for the sake of the economics of this scheme and if you take the large scheme—and I am not really sure in my own mind that the large scheme would be the first one to be done, but if you took the large scheme—then there would be tremendous pressure to get the work done as quickly as possible because that would lead to the cheapest capital cost of completion.

Now, the limiting factor in the planned schedule is the production of turbines, and it is beyond me to say where turbines would be produced. It would have to be more than one source of turbines. Whether they would come from the United States or Europe or whether they would be extra plants in Canada, I couldn't say.

Senator MITCHELL. You couldn't say now, but if this project is built, it would be built by the Tidal Power Corp.

Mr. BAKER. I think it rather unlikely that the Tidal Power Corp. would be the proponent. I think that my corporation would not be the constructor and certainly not operating the project.

Senator MITCHELL. Who would be, Mr. Baker?

Mr. BAKER. Our first vision of the thing, and the one we still are very fond of, is seeing the thing go ahead as a consortium of utilities in which the utilities, U.S. utilities would have interest and management rights—quasi-equity, let us say—in accordance to their participation and the energy rights they had. At the extinction of those rights, the extinction of their interests, their management rights would lapse.

Senator MITCHELL. So you anticipate this would be built by a private nongovernmental entity, a consortium of private utilities?

Mr. BAKER. That is one scenario. On the other hand, if there were a purely commercial entrepreneur, then we would have another set of circumstances. It would then look more or less like Churchill Falls where a consortium of private companies did the construction and entered into sales contracts with utilities.

Senator MITCHELL. Would you take a moment to describe what the Tidal Power Corp. is? Is it a public entity?

Mr. BAKER. In our country, it is called a crown corporation, Mr. Chairman. It is owned by the government of Nova Scotia. And it has substantial objectives, the exploitation of the tidal resource. And it has in the legal sense, all the rights and obligations of any other corporation formed under the law.

Senator MITCHELL. The reason I raise the question of jobs during construction is that in this country, at least, one of the perceived benefits in large projects such as this particular hydroelectric project is, of course, the creation of jobs during the construction period, both in terms of onsite construction and provision of materials such as, in this case, the turbines required by the project. Ordinarily, of course, I am certain that is a factor in the minds of the Nova Scotian government.

Mr. BAKER. Undoubtedly.

Senator MITCHELL. Unemployment being what it is there as well as in the United States. And ordinarily, of course, it would be expected that the benefits would flow to the area or the country in which it is being constructed. You have, however, here an unusual case in which, according to your own study, 90 percent of the power will be exported to the United States, and American participation will be essential if the project is to go forward. Under such circumstances, it seems to me it would make sense, at least to present the opportunity to discuss the prospect of American participation in a more direct and immediate sense.

Mr. BAKER. Yes, Mr. Chairman. I guess my only additional comment on that would be come what may. If the project were to go ahead, it would have perhaps a half billion dollars' worth of line construction work to be done entirely in the States. There would be a good deal of need for technical design services, managerial services and a lot of those come from the need of the United States. The onsite construction, I think it might be rather out of the question on account of logistics to make any U.S. procurement, and I have already mentioned the turbines.

Senator MITCHELL. Right. Mr. Baker, I thank you. I want to conclude by saying that I welcome your attitude toward an assessment of the potential environmental impacts, and specifically your proposal for a joint United States-Canadian entity to participate in that assessment. That is very important to us, and I expect to follow through with you on that, both personally and along with other American officials to try to develop the entity, or select or develop an entity, that will be most suited to that task, and that gives us some reassurance that we will play a direct and meaningful role in that assessment and in the evaluation of the assessment. That is very important to us.

Mr. BAKER. Thank you very much.

Senator MITCHELL. Thank you very much, Mr. Baker, for coming. Your full statement, Mr. Baker, will go into the record as I indicated earlier.

Our next witness is Dr. David Greenberg of the Bedford Institute of Oceanography. Doctor Greenberg, we welcome you. We are aware of the work you have been doing with respect to this subject, and we look forward to your testimony.

STATEMENT OF DR. DAVID A. GREENBERG, BEDFORD INSTITUTE OF OCEANOGRAPHY

Dr. GREENBERG. I think I better perhaps begin with the usual civil service caveat that the opinions that I will be expressing are my own rather than those of my employer, the Government. And also that my specialty is a rather narrow part of physical oceanography, but the nature of what I have done spills into a lot of other fields, and I will try to make it clear when I am stepping outside and making more tentative conclusions than those I am very familiar with.

The initial goal of this work was to predict the tide at a tidal power barrier to figure out what power would be available from a barrier, and that would work its way into the economically feasibility, economic viability of the scheme. And we ended with a second goal that the same work might be useful in determining environmental impacts both around the barrier and how far away from the barrier they might occur. The technique used was one of computer modeling, and it is now a very well tool. It is used in such places as Jamaica Bay by the Rand Corp. in their studies of pollution. The British are using it in the north seas to study storm surges to figure out when they are going to close their Tens barrier to keep from flooding London, and the Dutch are using it extensively in their government projects for dyking of the lowlands.

Our Bay of Fundy-Gulf of Maine studies gives perhaps some surprising results when you first look at them. They indicate a tidal power barrier at the head of the Bay of Fundy would change the tides throughout the Bay of Fundy and the Gulf of Maine. Three dams are contemplated. George Baker talked about two. The third and less economically viable, the two smaller schemes one which he denoted A–8 across Cumberland Basin in Chignecto Bay and another beside it up across Shepody Bay both in Chignecto Bay had very similar type changes. They would cause a drop in the tidal amplitude; that is to say, the high tide would be lower and low tide would be higher so you would end up with a smaller tidal range. Due to these areas at the barrier site and throughout the head of the bay, that decrease would disappear around the central part of the bay and as you got to the mouth of the bay, you would start to see an increase, and that increase would exist throughout the Gulf of Maine. For these small schemes, we're talking perhaps at a 2-inch higher high water, 2-inch lower low water effect throughout the coastline and Gulf of Maine.

Senator MITCHELL. Do I understand that you are saying that in the immediate vicinity of the dam, high tide would be higher or lower?

Dr. GREENBERG. High tide would be lower.

Senator MITCHELL. High tide would be lower. Low tide would be higher. That is getting away from that on the coast of Maine, those effects would be reversed?

Dr. GREENBERG. That's correct.

Senator MITCHELL. I see.

Dr. GREENBERG. The larger of the three schemes, the B–9 scheme, the one at Economy Point in Minas Basin could give rise to a drop at the barrier in the very near vicinity of the barrier but other than that,

throughout the head of the Bay of Fundy and throughout the Gulf of Maine, we would see an increase in tide; and that increase could be as high as 8 or 9 inches in the upper Bay of Fundy. That is 8 or 9 inches higher high water; 8 or 9 inches lower low water. That decreases slightly—increasing slightly to say around Boston, we can still see 6-inch increases in high water, decrease in low water.

In all three cases, the effects tend to disappear as you round the corner of Cape Cod and get by Hyannis. Or as you round the Cape stable and start to work up the Nova Scotia coast.

Superficially, these changes seem a little far fetched, and we wonder how a dam a couple of miles long could effect the tides hundreds of miles away, and we wonder if we can really believe this. We think we can.

I will put forward three of the reasons that go into our thinking. The first is we have put the model through an awful lot of testing and upgrading, and we keep on getting very similar answers. Some of the quantity of answers, the exact answers have changed or been modified as we go to better and better schemes. But they always predict the same sort of thing with a drop at the barrier and an increase for erosion.

Second of all, there have been two independent researchers who got the same sort of answers with different but not as well calibrated or much coarser models. That is to say, they are seeing decreases at a power tidal barrier and increases throughout the Gulf of Maine. One of these studies addressed a very different sort of problem but was able to give the same sort of result and another study which was a very courser type model.

And the third reason that I think we can believe this. We can explain physically what is happening, and the physical phenomenon is that of resonance if I can go to an analogy. If we sit in the bathroom and rock back and forth at the right sort of frequency, with almost no energy at all you can pump the water right over the ends of the bathtub. If you go the wrong frequency, you end up with a bunch of waves in the bathtub. The Bay of Fundy and the Gulf of Maine might be considered as one bathtub and the rocking is taking place at the edge of the Continental Shelf, and that is what is driving the tides in that area. The right period for the Bay of Fundy in the Gulf of Maine is about 13 hours, the tides are rocking it back and forth at about 12½ hours. That is not exact, but it is close enough to give the very high tides that we find in the Bay of Fundy now.

Senator MITCHELL. Could you explain again the relationship of the two times you just stated?

Mr. GREENBERG. The 13 hours is the period that the Bay of Fundy by itself would naturally oscillate. The period that it responds most, the Bay of Fundy and Gulf of Maine system responds most at a period. It doesn't take very much energy to get a vary large output of energy at that frequency.

Senator MITCHELL. What occurs every 13 hours.

Mr. GREENBERG. Naturally nothing. It is like a swing hanging there with somebody on it. You need somebody to push it. If you push it at the right frequency, then it is easy to keep pushing it to get it higher and higher. If you try to push it not at the frequency at which it would

naturally swing, then you end up with a disjointed, jerky sort of swing.

Senator MITCHELL. But where do the 13 hours come from?

Dr. GREENBERG. The 13 hours come from an analysis, one of the previous studies that I have mentioned briefly that suggests that is the right period for the Gulf of Maine. Actually, there are two studies where they have analyzed the available tidal data, and there are different frequencies hitting it, not just the 12½-hour data. And when you look at the response to the difference frequencies, you can say, OK, this is peaking at 13 hours. This is where the Bay of Fundy-Gulf of Maine would most fully respond.

Senator MITCHELL. Well, I understand the 12½-hour period. There is a physical event that is associated with that. I am trying to understand what physical event occurs within the 13-hour period.

Dr. GREENBERG. There is no physical event that occurs in the 13-hour period. That is, as I say, like a swing sitting there all by itself with somebody on it. And you could calculate like a pendulum what the right frequency or period of that pendulum is the same way as a clock swinging back and forth at a constant second per back and forth.

Senator MITCHELL. And is it the close proximity of those two figures in time that leads to the pronounced effects that would be felt here?

Dr. GREENBERG. Yes. It first of all leads to the high tides we see in the first place. And by chopping off the end of the bay, we are pushing that 13 hours even closer to the 12½ hours, and that is why we see the whole system respond. So the effect is because the whole system is moved a little bit closer.

Now, it is more complex than just a simple swing or just a simple bathtub, so there are more effects. We see the drop at the head of the bay and the other things that get involved, but the overall effect in the full system is because we are moving the whole system closer to the tide.

Senator MITCHELL. You are saying that there are two independent time periods which happen to closely coincide and which therefore in conjunction cause a very pronounced effect with an already existing pronounced effect that would be made even more pronounced by the construction of the dam which would shorten the bay?

Dr. GREENBERG. That's correct.

Senator MITCHELL. Thank you. Continue.

Dr. GREENBERG. OK. I guess the next question is, how significant are these changes, the 2 and 6 inches added on top of the tide? If we look at one extreme, and we forget about anything the weather can do to you, we can say that the tides are very variable by themselves. And if we take perhaps the example of Boston, because everybody likes to think of closing Logan Airport every high water, we can say that they have an average tide of about 9 feet. But over the course of a year, the lowest tidal range would be about 6 feet, and the highest tidal range would be somewhere around 12 feet. We, at 6 inches to high and low water in each case, we are changing that tidal range to 7 to 13 feet instead of 6 to 12 feet. And so most of the time, the new tidal ranges that you see from tidal power are within the ranges that are already seen in nature today.

If we now add what weather does to the water levels, there can be storm surges that will change the water levels by up to 5 or 7 feet from

the predicted astronomical tide from bad storms, and we have incidence of those in the upper Bay of Fundy as well as incidences down here. Add to that any kind of wave activity in 6 inches seems absolutely negligible, but that is entirely the wrong way to look at it as it stands. Superficially, you might not see it every time, but it would be there.

If you look at another extreme, if we define the usable property along a shore as somebody owning his property up to the high waterline and if we say a beach slope is somewhere about a 1-foot rise for every 40 feet inland and that is a low beach slope, then a 6-inch rise in high water would take 20 feet off the beach frontage of a property. If we could multiply that by the length of Cape Cod times the cost of an acre in Cape Cod, we would end up with a fairly large number, I think. But again I think that is a rather extreme view.

Senator MITCHELL. Big compensation, Mr. Baker.

Dr. GREENBERG. Some of us don't make that much in 1 week. I think it is more accurate to say that the areas that are already sensitive to high water now would be the ones that are most at risk, and anything that is not senitive at all to high water now might end up with a marginal risk.

We have already mentioned areas with low beach slope. That might include things like salt marshes which depend on occasional floodings by the higher high waters or the storms to change nutrients, and the salt marshes tend to be the natural resources-type places where sea birds and water fowl like to be protected. Increased flushing might be beneficial, it might be detrimental. A good understanding of these ecosystems in necessary before we can really predict what could happen there.

I have mentioned storm surges already. The problem with flooding isn't usually just a storm surge or isn't usually just a tide. The problem is when the higher high water of a tide meets a large storm surge, if these 6 inches were to change the return period of a flood, it is a joint probability of these two, if it changes a 40-year return period to a 39½-year return period, I don't think anyone woud bat an eye. If it changes it from a 40-year return period to a 20 year, then we have to worry. This sort of 6-inch difference could make a flooding situation out of a nonflooding situation or it could make a flooding situation much worse than it would otherwise be if the flood, if it happen to hit at a high water time. And, almost by definition, your flooding would take place at a high water time.

Another area that you would worry about are areas built very close to high water. There is at least one restaurant built out on a dock that probably points to the fact that the highest tide of the year, its floor is about 6 inches above the water level. That seems a little improbable, and I don't understand why anybody would build there, but that type of thing seems to occur. I think maybe I'll stop there and let you ask questions instead of going into things that might not be so interesting.

Senator MITCHELL. First, let me ask you, Dr. Greenberg, to briefly identify the Bedford Institute of Oceanography and your position there.

Dr. GREENBERG. I am a research scientist at the Bedford Institute of Oceanography. It is a Government institute, part of the Department of Fisheries and Oceans. It is part of the Government department.

Senator MITCHELL. Is that the Provincial government or the Federal Government?

Dr. GREENBERG. That is the Federal Government of Canada. It is actually several departments at that institute. There is a geological group that is part of energy mines and resources, and there is a small bird group that is part of the Department of the Environment. So it is a multidepartment facility that is dedicated to ocean-oriented research.

Senator MITCHELL. Have you used the state-of-the-art technology in constructing the models to arrive at this information or are there other methods available that increase the accuracy of the models you have used?

Dr. GREENBERG. It is state-of-the-art technology that was used. I think since the time of the original studies, the technique is being, I would say, better verified, but hasn't really been advanced that much since the studies have been done. People are trusting more and more.

Senator MITCHELL. Since this type of modeling is difficult, especially for something as large and complex as the tide in the Gulf of Maine, would you find it useful to have an independent study of the physical effects to compare wth your model projections?

Dr. GREENBERG. I think anything that is going to be done has to be done well. One of the things that we found as we went through and did the studies which were spread over several years even before I started doing the work for Tidal Power was you have to get some local type knowledge of the area, what is important, what has to be modeled. There are sort of off-the-shelf models that you can come in and apply to an area, and I don't think that they would work in this sort of situation because of the difference of having to get different scales up in the head of the bay and also include the full Gulf of Maine so I don't think the standard sort of approach would work. You need somebody that is going to learn something about the Bay of Fundy and then go at it and study it.

Would it be useful? If it gets the same answer, it is going to be very useful. If it didn't, everybody has to run away and start scratching their heads. And I don't know whether you start pointing fingers or how it works. If it is going to be done, it has to be done well I guess is the answer.

Senator MITCHELL. Has the data which you have developed so far been made available to the Tidal Power Corp. and to those who are participating in the development of this project?

Dr. GREENBERG. Oh, yes; and I sent results of the model to people in the States as well for their environmental studies. Some people have actually created models in this area that I have sent some of the input data from the model to them so they could create their own models.

Senator MITCHELL. Do you expect to participate actively in the further assessments that are to be made in connection with this project?

Dr. GREENBERG. I can't say positively I would. I say the chances are best that I would not. The reason is that my position as a research position, my interest in the Bay of Fundy initially was as a research type topic. We are now getting more into an engineering type study where we are going into more fine detail that way, and the pure research aspect is not so prevalent now. And I don't think I would be encouraged to get involved with it from the sort of people at the research institute where I work.

Senator MITCHELL. Are you saying that you have done everything you can do and you have developed this information, and now it is up to others to evaluate and utilize this information as best they can?

Dr. GREENBERG. I would say I have done most of what I would like to do, and most of what needs to be done is not really my major field of interest. I have not done a lot of work on tidal power in the last 3 or 4 years. I am following through on the work that was done earlier.

Senator MITCHELL. Have you had any disagreements with the Tidal Power Corp. concerning the potential environmental impacts of this project?

Dr. GREENBERG. None at all.

Senator MITCHELL. I see. I am not sure on your earlier answer. Do you think that all of the research or most of the research that needs to be done has been done, that all the necessary information is now available, and that all that is now required is the evaluation and critical judgment of that information?

Dr. GREENBERG. There probably will be another very good model done of the area. I would be surprised if it is going to get any different answers so I guess some day it will be useful to look at maybe a much better resolution, much more expensive model that I have had done.

Senator MITCHELL. Well, you see, that is an important question in light of what we discussed earlier. Mr. Baker discussed a joint U.S.-Canadian entity to make what we have been referring to as a detailed environmental assessment. Now, of course, an assessment can be the development of further information and its evaluation or simply the evaluation of existing information. I gathered from your earlier answer that you thought there wasn't much more information to gather, and that all that is required now is the making of that kind of judgment. Is that what you are saying or do I misunderstand you?

Dr. GREENBERG. I think most of the information that people need to work with at this stage is available. I think we have got good answers for what is going to happen around the coast of Maine, and that is what needs to be developed more as far as people. We now have an idea of how the tides are going to change. We want to know how those tides impact on other systems. I think if when we get into our—closer to the precommitment stage I guess as George referred to it, then I think would be the time when you want a very, very accurate high resolution model that is going to tell you everything down to the end detail. I think with the information available now, you can make very good assessments of how important the environmental damage would be.

Senator MITCHELL. Thank you very much, Dr. Greenberg. Your testimony is very helpful.

The next witnesses will be a panel, Mr. Yentsch, Dr. Larsen, Dr. Topinka, and Mr. Timson. If they will all come forward please and take seats at the table.

Good morning, gentlemen. We look forward to your testimony. I assume you were here earlier when I indicated the hearing would have to conclude at 1 o'clock. I would ask each of you to summarize your prepared remarks if they will run over 10 minutes. Any written statements you have prepared will be inserted into the record in full. We will take the witnesses in the order that they are listed.

Mr. Charles Yentsch is the director of the Bigelow Laboratory. Mr. Yentsch, why don't you begin.

STATEMENT OF CHARLES YENTSCH, DIRECTOR, BIGELOW LABORATORY

Mr. YENTSCH. My statement is going to be very brief. My colleagues set me up in this position to sort of be the leadoff candidate for our group. What I thought might be helpful to you is to just very briefly explain why the Gulf of Maine and the surrounding banks are such productive fisheries. I think that would be helpful for the analysis of this committee.

If I had to sum it up in a couple of words, I would just say tidal stirring, and as you know, stirring requires work and the work is done by the tides, as you just heard from Dr. Greenberg. Now, you could respond and say, well, how does that relate to a very fertile fisheries area? As to work like this, first of all, let's look at an area that is not stirred—the central parts of the Gulf of Maine are not stirred. They are receiving at the moment intense amounts of heat. The surface water tends to become lighter than the deeper waters, and this produces a condition we call a stability condition, stability in the water masses.

Now, what is important to this stability relationship is that the organisms that really produce the fertility are required to be in the surface waters, and they require fertilizers much as your garden needs to grow. Now, in the process of growing in these surface waters, they deplete the fertilizers and the real reservoir then is in the deeper, colder water underneath. And the only way you can continue to sustain this fertile region is to have this mixture go on. So it is the tides that keep it stirred up, keep the fertilizers in contact with the organisms that need to grow to feed the fisheries, and that is why our region is so fertile.

We know the measurements that the Gulf of Maine and its banks are approximately one-third tidally stirred all of the time. Now, the importance of this number is that two-thirds of the annual production of dry algae, eventually plankton, eventually fish, are produced in those areas. So, two-thirds of the annual production is produced by one-third of the area of tidal stirring.

We can pose the question, well, what will happen if we increase tidal flows, and that is what we expect will happen with this dam. It might in some cases actually increase the fertility of some of the areas on the Gulf of Maine; however, this needs really vigorous studying of the modeling of the type Dr. Greenberg is talking about actually married with a biological model. If we slow down the tidal flow, the net effect will be that the surface waters of the Gulf of Maine will become much warmer and very much less fertile.

Now, if there are no further questions, I would like my colleagues to take off on their testimony. They have done a great deal more research in this area than I.

Senator MITCHELL. I do have some questions, but I will wait to hear from the others. Dr. Larsen, you are next. Perhaps you could identify yourself briefly.

STATEMENT OF PETER LARSEN, RESEARCH SCIENTIST, BIGELOW LABORATORY

Dr. LARSEN. Thank you. My name is Peter Larsen I am a research scientist at the Bigelow Laboratory. In 1979, at the request of the Passamaquoddy Tribal Council, which was seeking information on the potential impacts of their own proposed tidal powerplant in Halfmoon Cove Tidal power facility. I attended the Fundy environmental studies committee meeting. It was at this meeting that I first became aware of the capability of large-scale tidal power development at the head of the Bay of Fundy to modify the tides in the Gulf of Maine. As a coastal ecologist, I became immediately aware that such changes in the tidal regime could have ecological effects, especially on fine grain environmentals such as mud flies and salt marshes.

At the time however, we did not fully appreciate and probably still don't, the entire suite of consequences that an alteration in the Gulf of Maine tides might hold for the New England region. We were intrigued, however, so my colleague, Dr. Topinka, and I attended the 1980 meeting of the Fundy environmental studies committee. This time we came away impressed that the potential for tidal power development at the head of the Bay of Fundy was being very seriously evaluated. That prediction of such development would result in a modified Gulf of Maine tidal regime was held in high regard by the scientific community. And finally, that no serious consideration was being given to the possible environmental consequences of a modified tidal regime along the highly developed New England coastline.

In June 1982, the Bigelow Laboratory was awarded a scoping contract from the Maine State Planning Office to evaluate the environmental implications of Fundy tidal power development to the coastal resources of the State of Maine. This work represents the first formal effort to assess our field effects of tidal power development. A number of people were involved in this, but in the interest of time. I will not go into them right now. The final report should be available from the State planning office in the very near future.

I would like to add at this time that the completion of the report was greatly helped by the enthusiastic cooperation of both the Fundy Tidal Power Corp. and the Canadian scientific community in general.

This hearing and the release of the reports from the State planing office are likely to generate considerable publicity on this issue. Undoubtedly, much of this publicity will focus on the more dramatic, short-term negative impacts and give the impression that the efforts going on here are in some way antitidal power or motivated to stop them from doing these. I want to make it very clear that this is not the case. We believe that the Northeast region is very dependent on foreign fossil fuel, and that tidal power may represent a very attractive alternative.

We also realize there is an environmental cost to pay for any type of energy. Our efforts are directed at documenting the environmental cost associated with Fundy tidal power generation so this nonpolluting energy source can objectively be compared to other alternatives such as nuclear power and coal-fired generation.

One might ask, why is there environmental concern about tidal modification? Concern about the far field effects have largely been played down by such arguments as the change in tides as small on an already large tidal range. The change is only equivalent to a small wave on top of the present high tide. The small surges due to atmospheric changes are larger than the projected changes in the tidal regime, and such a little change will be lost in the noise.

We contend that the predicted changes in tidal regime are not the equivalent of these random changes. There will be a permanent change in the tidal base upon which all other influence will fall. Although the change may be lost in the noise of a short term record, there would be a shift in the tidal base observable over long time periods. The percentage change in tidal regime is also larger in the more developed western Gulf of Maine than it is in the Fundy region. When one considers the length of coastline affected, it is easy to visualize even the small effect accumulated over such a large area would be grounds for concern.

We should put these projected tidal range changes in the context of the presently rising sea level. The small scale but long-term sea level rise by many parts of the world can demonstrate that even small changes in the land-sea interface can be of environmental significance. While these changes about 3 millimeters per year in New England are small compared to annual variations in sea level, and atmospherically induced changes, these changes are unidirectional, that is a misprint in my text by the way, and have historically resulted in the loss of coastal land and structures through erosion and flooding. Whereas the Fundy proposal will not change sea level, it will elevate the high tide level which in terms of coastal planning and management effects land and sea boundary. If one can accept there are environmental problems associated with long-term rise of sea level, it must be clear that the predicted rise in the high tide level will also have environmental consequences associated with it.

One of the principal differences between the phenomenon of sea level rise and enhanced tidal regime resulting from Fundy tidal power is the rate of change. To date, the natural rise in mean sea level is essentially imperceptible on the day-to-day or year-to-year scale of human activity. Geological and biological systems have been able to adapt gradually. By comparison, the proposed tidal range increase will be relatively rapid, and therefore potentially more disruptive.

In addition, there are phenomena related to the predicted tidal regime change which would not necessarily result from a sea level rise alone. These include but are not limited to a lower low tide level, a larger intertidal zone, stronger tidal currents and increased estuarine flushing.

New projections of future sea level rise have become available in the last few months. A study funded by the U.S. Environmental Protection Agency predicts mean sea level will rise due to thermal expansion of the sea surface from 2 to 10 feet by the year 2100. At the very least this represents almost twice the rate of natural sea level rise experienced in recent history.

The Gulf of Maine has also experienced a marked increase in tidal range in the last 4,000 years. This increase appears to be continuing at

a rate of about 3 millimeters per year, that is about 1 foot per 100 years. This rate should accelerate as some function of the increased sea level.

In other words, the New England coastline may experience very dramatic natural changes over the next century due to large scale patterns of sea level change. These changes will have serious socioeconomic impact.

The consequences of tidal regime changes caused by Fundy tidal power construction need to be evaluated in the context of these global changes. Indeed, it may be wise to reevaluate the engineering and economic feasibility of Fundy tidal power in light of projected sea level changes.

I will now just very briefly consider or list some of the environmental consequences that may be associated with this predicted 30 centimeter change in tidal range. My colleague testifying today will discuss some examples and many more are contained in the documents which I will submit in evidence. Our purpose is to demonstrate that the range of coastal habitats, uses, and functions that might be influenced by a small increase in tidal range.

One of the most obvious consequences is a loss of terrestrial habitat, the land-sea interface will be moved further toward the land.

Dr. Graham Giese of the Provincetown Center for Coastal Studies has estimated and is part of our research team that a 15-centimeter increase in the high tide level would result in a loss, a submergence of 4,200 acres along the coast of Maine. This is about a 2½ meter, 8 foot, strip along the entire coast of Maine. At any given point, of course, the strip lost to submergence would depend on local topography.

Using Old Orchard Beach as an example, Dr. Giese was able to estimate a profile retreat as the landward movement of the beach face about 20 meters over the next few decades.

Some other potential impacts, and I want to avoid using the word impact as a matter of fact, so potential consequences because some, especially the longer term ones, would be considered beneficial to the environment. It is mainly the shorter term impacts associated with the loss of land and buildings adjacent to the sea that are the negative impacts.

It has been predicted that the sewer system of the city of Portland would have to be retrofitted if the tidal range was increased because of its extremely low head. This will cause a major cause. In the short term—well, Dr. Arthur Spiess of the Maine Historical Preservation Commission believes that erosion is the worst threat to archeological sites in Maine today. He believes that a 6-inch tidal amplitude increase, that is half of the tidal range increase, would be a disaster. He estimates that over 700 shell heaps and other coastal sites representing 30 percent of those known to exist in Maine will be threatened by such an increase in range.

Other concerns are associated with over low water particularly in terms of the suitability of particular dock or pier at low water in navigation and small harbors at low water and so on. There are potential effects on the quality of ground water as the depth of the fresh water lands or actually the brackish water lands is a function of the tidal cycle or the tidal range. If the tidal range increases, this mixed layer will also increase in thickness and ground water wells would experience a decrease in water falling.

Some other aspects which I will just list in no particular order and making no attempt to be comprehensive but just to give you an idea of the scope of some of the things, both negative and beneficial that we have to consider. Associated with the larger tidal range, there will be stronger tidal currents which means that the water temperature might decrease a bit. Tidal excursions will increase. The tidal prism of estuaries will increase. These things together may lead to increased fog, stronger onshore winds, more difficult search and rescue operation, more difficult oil spill containment but also better pollution assimilation in the harbors and estuarine areas which would be considered beneficial. Tide tables would have to be changed. The stronger tidal currents might make ship maneuvering ability more difficult. The fishermen tell me they would have more trouble dragging because of stronger tidal currents and need more horsepower in their boats. The patterns of icing in the winter and the break up of that ice would be changed.

On the beneficial side, the intertidal area would be increased, meaning there might be more shellfish resources, more marsh area. In the case of on protected beaches, beach area may actually increase. And in general, there would be a higher—and Charlie Yentsch mentioned, a higher degree of productivity in the Gulf of Maine as a whole. I will stop there to save time for others.

Senator MITCHELL. Thank you, Dr. Larsen. Your prepared statement is somewhat more detailed concerning the consensus that you have described, and that written statement will go into the record in full. We now have Dr. Topinka.

STATEMENT OF JERRY A. TOPINKA, RESEARCH SCIENTIST, BIGELOW LABORATORY

Dr. TOPINKA. My name is Dr. Jerry Topinka. I have been a research scientist at Bigelow Lab for 9 years. This testimony will cover three areas. First, a perspective will be provided on tides and predicted tidal changes. Second, some of the more important biological influences will be discussed; finally, some major research needs will be identified.

We must realize that the ebb and flow of tides is an important feature of coastal Maine. An intertidal zone is created between high and low tide marks which supports unique communities of plants and animals that are of considerable biological and economic value. Tides also influence water currents which mix and disperse vital nutritive materials, biological products, and pollutants. One has only to motor or sail along the coast of Maine to gain some of the appreciation of its vast length. It has been estimated this rugged and convoluted coast supports an estuarine and marine shoreline totalling over 4,000 miles. It is this enormous coastline which is influenced by tidal action.

It has been predicted that the 5-mile-long tidal dam in Minas Basin will increase the 3-mile tidal range by approximately 30 centimeters to produce an increase in tidal range of approximately 10 percent. Although in relative terms this is not a great change, the significance of an environmental change is not only dependent on the degree or dramatic nature of the change. It is also dependent on the size of the area affected. This 10-percent increase in tidal range will be felt along vir-

tually the entire coast of Maine. Thus, tidal effects will encompass virtually the entire Gulf of Maine and its shoreline. It is this widespread nature of tidal effect that renders them potentially important.

How and to what degree will these widespread tidal influences manifest? Will such tidal changes and some of the effects they produce be insignificant to be lost to the natural variability of noise of the tidal system? Consider that predicted 10-percent change in tidal amplitude is set against the background of extremely large tidal variations in the spring and neap tides and atmospheric influences. Isn't this predicted 10-percent change therefore an insignificant part of the natural variability of the tidal pattern? The answer is a definitive no. This increase in tidal amplitude is not just a part of the natural noise of the tidal system. Such a 10-percent change represents a long-term, one-way shift in the tidal range background upon which all of the variations are based.

If we examine natural biological populations, we soon discover that they exhibit large natural variabilities. Would tidal effects on such populations be important? Would they be measurable, and would it be possible to later ascribe these alterations to an increased tidal range? While some populations may undergo large dramatical alterations, many biological populations must be recognized that the changes due to tidal power construction may not easily be discernable. In many complex systems, it may be difficult, if not impossible, to ascribe an altered population to a change in tidal regime alone.

It is probable that such tidal alteration may not be statistically apparent or verifiable as trends for many years. As with the physical shift in a tidal regime, however, such population changes are likely to be real one-way shifts and baseline population conditions and be of real importance in that the mean or average baseline conditions have been altered.

The degree to which the intertidal zone would be expanded will depend on the slope of the shorelines. A 30 centimeter increase in tidal range will produce significant—will produce little significant increases in absolute intertidal area on steeply sloping shores, such as many rocky shores. On gently sloping shorelines such as these found on tidal marshes, a 30-centimeter increase or 6-inch increase at high water in tidal range may greatly expand intertidal area covered by Maine tides. A change in tidal inundation patterns will also produce some significant changes in the distribution of intertidal organisms. In the intertidal area, plants and animals are often distributed in vertical zones or layers with respect to tidal inundation due in large part to the requirement of tolerance for exposure to air and associated stresses.

The vertical zonation of plants and animals would be altered in several ways; first, there would be a widening of each vertical band of biota. Where shore slopes are uniform a 10-percent increase in tidal amplitude will yield these zones that are approximately 10-percent wider. Many of these zones however will be also vertically displaced. Where suitable habitat is available, this displacement and an increase in area would be expected to eventually result in the greater biological productivity leading to a 10-percent increase in intertidal biota which would include organisms such as soft shell clams, muscles, seaweed, and marine worms.

Of all of the intertidal habitats, salt marshes are the most vulnerable to changes in tidal regime. Transition between upper and lower salt marsh areas occurs as a result of tidal inundation where upper or high salt marshes are infrequently flooded and low salt marsh areas are regularly flooded. The transition occurs in the vicinity of mean high water. The position of this transition zone coupled with the great horizontal expansion of gently sloping high marsh makes this region highly susceptible to the influence of a 15-centimeter increase in mean high water. The upper marsh area vastly exceeds the low marsh area and will be the salt marsh region to undergo the most dramatic change as low marsh plants take over low marsh areas and upper high marsh boundaries are extended landward, this changing the character of the marsh.

This change in plant population and attendant changes in marine animal populations may well be dramatic. Maine possesses only about 17,000 acres of the salt marsh, despite its extensive shoreline. This renders salt marsh habitat relatively rare and valuable. Salt marshes are well known to produce important regions for various juvenile fishes and provides areas for cover, nesting, rearing of young, feeding of shore birds. Given time, sedimentary deposition will elevate marsh levels to the point where a new equilibrium is established and salt marshes are again stabilized. This process may, however, take many years during which salt marshes may be severely disrupted.

An increased tidal range will also result in increased tidal currents in addition to patterns of coastal inundation. These changes in tidal currents are expected to produce some significant changes in many physical and biological components of coastal systems.

Increased current velocities will be expected to change erosional depositional patterns at sedimentary areas such as salt marshes, and mudflats and soft bottoms. Many such regions are expected to be eventually reorganized, some even in different locations.

Increased current velocities will also enhance vertical mixing processes and exchanges between estuarine and marine waters. Together with increased plant production due to expanded intertidal areas, such water movement processes are anticipated to stimulate primary production of organic food matter by phytoplankton, seaweeds, and salt marsh plants. This should lead to a greater secondary production of marine and estuarine animals including some commercial species. Such an effect would be highly beneficial. The greater dispersal of biological products, such as invertebrate larvae of clams, should also prove beneficial.

Increased current velocities may however promote the ingestion of red tide cysts during nonbloom conditions and lead to greater red tide formation and dispersion. This would contribute to high levels of the red tide contamination of vulnerable shellfish. The growth of fouling organisms, such as barnacles on marine surfaces, could also be increased and ice abrasion and damage would tend to be greater.

Also as a result of great tidal amplitudes, flushing of estuaries would be improved. Virtually all pollutants entering an estuary would be dispersed and flushed from estuaries at greater rates resulting in significantly cleaner coastal waters.

The effects briefly described here are among some of the most important effects of an increased tidal range. Many more potential influences could be discussed. From this it is clear, however, that both beneficial and detrimental influences are possible. Many will be important but few will be as dramatic as those expected for salt marshes. One would suspect perhaps that the casual observer of the coast would notice few major changes. He might be correct. By and large, the visual character of the coast would remain much the same.

Changes in the biological productivity, however, are also of considerable importance and must be understood if we are to protect our vulnerable coastal resources. In order to adequately reevaluate and weigh the beneficial and detrimental aspects of the 10-percent increase in tidal range, many issues must be addressed in more detail. While some issues can be adequately explored with existing data, other effects require considerable field work.

As a first step, it is suggested that a 2-day symposium be sponsored to consider both the scientific and socioeconomic issues. This scientific meeting should be opened to the public. This symposium would help to facilitate the exchange of ideas of experts in many fields. A detailed proposal to conduct this symposium has been formulated already by the Bigelow Laboratory.

Increases in tidal area will also occur as a result of this higher tidal range. It is necessary to know how much the various intertidal habitats will be increased in terms of area. A detailed work plan has also been drawn to address this topic area. How much area will be lost to subtidal and terrestrial borders? How will the gains and losses be distributed among the various segments of the coast? What will be the biological responses to these changes? In particular, to what extent will salt marshes be influenced?

Finally, increased tidal flushing of estuaries will take place which may increase primary productivity of organic food matter and disperse pollutants more quickly. To what degree will flushing be changed in various estuaries? How will systems respond in terms of temperature, salinity productivity, pollution assimilation, and community distribution?

These are among the most important topics which need to be addressed. Such studies should supply much of the information needed to evaluate tidal power influences along the coast of Maine.

Senator MITCHELL. Thank you, Dr. Topinka.

Mr. Timson.

STATEMENT OF BARRY S. TIMSON, CONSULTING GEOLOGIST

Mr. TIMSON. Thank you, Mr. Chairman. My name is Barry Timson. I am a consulting geologist, and I worked on part of the Bigelow study on the impacts of the tidal power project on the resources of the State of Maine. My comments are fairly well restricted to the changes which the tidal power projects might bring to coastal storm surge levels and subsequent impacts on beaches and navigation channels in Maine. Canadian tidal power projects are forecasted to increase our semidiurnal tidal amplitudes by 30 centimeters. This will also lead to an increased coastal surge level, coastal storm surge levels of 15 centi-

meters. Almost all the storms passing through the Gulf of Maine require 12 hours or more to do so. This increase in surge levels of 15 centimeters will, in effect, increase the number of damaging storms which impact the coast by a factor of 2½.

I wish to make it clear that the projects will not influence our climate regimes, and thereby increase the number of storms, but will increase the storm surge levels which we have experienced in the past.

For example, Stone & Webster Engineering Co. as part of a previous Federal flood insurance study determined that a coastal surge level of exceedance probability 13.3 percent or a storm as most of us would know as a 7½ return storm caused unexpected beach erosion and damage to manmade coastal structures. This was the threshold storm. Storms of higher or greater than 13.3 percent probability cause insignificant erosion or damage. Those of lower exceedance probability caused even more significant erosional damage. If 15 centimeters of tidal height are added to historical coastal storm surge levels, a coastal storm of 45 percent in exceedance probability or 2.2 year return storm will become the threshold storm which causes significant beach erosion and coastal damage.

From 1940 to 1979, the Gulf of Maine experienced only 11 storms of 13.3 percent exceedance probability, 30 storms of 45 percent exceedance probability. If the tidal power projects had been completed in 1940, Maine, New Hampshire, and Massachusetts would have been impacted by 30 storms causing significant damage rather than 11.

In addition, the magnitude of storm damage expectancy will increase. With an increase of the tidal amplitude of 15 centimeters, a 100-year storm of today will cause storm surge levels equivalent to a 300-year storm. A 50-year storm will be equivalent to a 200-year storm, and a 25-year storm will be equivalent to a 100-year storm. All of us in New England are familiar with the February 1978, northeast storm and the damage which it caused. This storm is taken by most as the storm of record and the 100-year storm. From 1940 to 1979, only one storm of this magnitude occurred. If the tidal power projects had been completed prior to 1943, storms of this magnitude or greater would have occurred.

These are facts on coastal storm surges certainly to be significant. Certainly warrants our attention as it translates into significant beach erosion, millions of dollars of damage to manmade coastal structures and facilities and probably increased deposition of sand and mud in harbors and some navigation channels.

I would like to go now into a consideration of the effects of storms on beaches and beach retreats which Dr. Larsen, I think, has already mentioned very briefly.

Geologists seem to be split into two camps as to whether beach recession rates are caused mostly by coastal storm wave erosion or sea level rise. I happen to be that camp that believes that coastal storms are the major controlling variable. Bruce Nelson, in a fairly lengthy master's thesis in 1979 determined that sea level rise in Maine can account for 9 to 12 centimeters of annual beach recession on many of our beaches. But the beaches are exceeding at a far greater rate at about 30 centimeters per year. Nelson as well as myself would attribute this to coastal storm erosion. I do not believe that the increased tidal amplitude alone

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will cause any more erosion on the New England coastal beaches than is otherwise being experienced.

Increased recession rates, however, will be experienced because increased storm surge levels will allow wave energy to be expanded higher, the beach profile allowing for deeper penetration of erosion. If we are correct in our assumption that coastal storms are the major controlling variable, beach recession, and the relationship between the amount of beach recession and storm energy linear, then the amount of recession which will be experienced by our major beaches because of the tidal power projects will be about 60 centimeters per year. This relationship is probably too simple to be reality, but we are looking at a situation where recession rates will increase probably from 1½ to 2½ times the present rates. The recession rates actually experienced may even be higher as recent investigations by the Maine geological survey and the EPA hint that sea level rise rates may be increasing in much greater rate than in the immediate past.

Now, I would like to simply direct my comments to some possible effects on coastal navigation. It is fairly well known now by geologists that much of the sediment that is deposited in shallow estuaries, lagoons, and coastal embayments is derived from the ocean, especially in New England.

Detmar Schnitker, nicely documented how important coastal storms are in eroding near and off-shore bottom sediments and transporting elevated concentrations of suspended sediment into coastal embayments along Maine. Much of the mud making up our tidal flats is derived from the ocean bottom. It has been observed that coastal storm erosion of barrier beaches and spits leads to increased deposition of sand in lagoons and estuaries behind the barriers. We should expect, therefore, that the tidal projects will increase the deposition in our harbors, mooring basins, and some navigation channels.

In light of my previous testimony on beach recession, those harbor and channel areas which have been dredged in coarse-grained or sandy back barrier embayments will experience more frequent shoaling. Areas such as Gloucester Harbor, Hampton Harbor, Wells, Camp Ellis in the Saco River and the Scarborough River, for example, will require more frequent dredging than in the past.

The 30-centimeter increase in tidal range projected as an effect of the power project will allow coastal storm waves to erode off-shore bottom areas never before effected, as well as allowing an increased expenditure of energy on the bottom areas which have been effected. This increased erosion capability coupled with the increased storm surge penetration will result in greater amounts of suspended sediment being delivered to sheltered navigation waters dredged into fine grain, subtidal and intertidal flats.

Some harbors and navigation channels will be unaffected as the preliminary assessment indicates that flushing rates will increase in estuaries, transporting more suspended sediment seaward than it is now presently the case. Deposition of fine grained sediments in well stratified estuaries, however, should increase. In some instances, deposition in these types of estuaries will be in areas where deposition does not now occur as the salt wedge will penetrate further landward due to the increase tidal range. Consequently, some harbor areas such

as Portsmouth, Portland, Royal River, and Winterport which is in the Penobscot River which are well stratified and historically have had fine grain material dredged from their waterways should require dredging more often in different areas than in the past.

It is not possible to be at all quantitative in determining the amount of increased deposition that will occur in these areas. Our research data base in this area is not as sizable as the beach recession base.

Suffice it to say, that if the tidal power projects are to be reality, this problem will have to be studied much more closely. Thank you, Mr. Chairman.

Senator MITCHELL. Thank you, Mr. Timson. Your remarks and Dr. Topinka's remarks lead me to conclude from the testimony we have had today that there are really two separate questions here in evaluating the impact of this project. The first is what effect will the construction of the dam have at Minas Basin on the tides, the second question is what effect will the increased tide, or the change in the tides, have on the coast?

Dr. Greenberg has indicated that at least from his standpoint the first question has effectively been answered, and while it would be useful to have an additional independent verification to confirm his conclusions, he said he would be surprised if it produced any different results.

It seems to me that based on the testimony you gentlemen have given that the second question has not been definitively answered, that is, you have reached some tentative conclusions, but I gather, particularly listening to you, Mr. Timson, that you have reviewed the existing research on the subject rather than having conducted directly independent research in the area.

I would ask Dr. Larsen, Dr. Topinka, and Mr. Timson to comment on this and to tell me whether my conclusion is correct or incorrect. If it is correct, would you specify the areas where you feel more research is necessary to arrive at a more definitive answer?

Dr. LARSEN. Yes. You are correct in what you say. When we began the State planning study, we interviewed a number of theoretical physical oceanographers to ask them their opinion of the adequacy of the Greenberg model, and I would say they were—whereas there were questions about certain details here and there, no one questioned the results. Some comments of this type are contained within the State planning report that will be submitted soon.

These people were all so confident in the results of the study. Rather than do any kind of review which was detailed—review which is out of our field of expertise, we decided to accept the Canadian projections politically that also seemed easier and then set off to determine, OK, if the tides are going to change this much, what is the impact on the coast of Maine, what changes can we expect in the components of the environment which are dependent on the tidal range, geology, biology, and to some extent socioeconomic aspects?

Where we go from here. I can probably talk all day. We won't. There are a number of items listed in the State planning report. I just briefly listed three of four here which in the interest of time I did not go into. There seem to be two sorts of time scales for the kinds of things that can be done to provide the interest we need. We do have

scientific expertise in the region and we also in many cases have a data base so some questions can be answered in a very short time period, a year or two. Other aspects are much more complex and would take 5 years, 7 years of very interactive work among a number of investigators or organizations.

Part of our concern indeed is that the 3-year precommitment study does not allow enough lead-time to answer some of the environmental questions, so we are concerned that the environmental work begin just as soon as possible. It could be in the best interest of everyone concerned, and we also think it would be scientifically more efficient to have cooperative programs with the Canadians so we don't plow over the same ground again, as Mr. Baker suggested.

The two or three things I would like to put out today as suggested areas of research is how significant are the projected changes in estuarine flushing rates. An estuarine flushing model is now operative at the Bigelow Laboratory. Information on floor rates, volume, tidal ranges of the various estuaries is also available. This model could be run for each Gulf of Maine estuary with an output field checked and results interpreted, in perhaps 18 months. This would give us an answer of do we need to worry about changes in estuarine flushing as being especially bad or especially good for the coast of Maine.

Some insight into the significance of the increased tidal current velocity can be gained by examining long-term tidal cycles. There are a number of tidal cycles that we can look at, and tidal current may vary by as much as 5 percent over some of these cycles. And some fishery biologists believe that the cycles and fishery landings are related to the changes in tidal currents which affect other things like surface water temperature, productivity, as others have said today. These long-term tidal records, temperature, and current statistics all exist. And with a small group of experts, we probably analyze these and see if—indeed, if a 5-percent change in tidal currents has some manifestation in a biological component such as fisheries landing, then maybe we should be concerned about the 10-percent increase. The expectation would be the increase in tidal currents would increase fisheries productivity, however.

Another exercise that could be done rather quickly is for a detail case study of one or more coastal communities. Get together a group of people, a geologist, biologist, hydrologist, waste water engineer, real estate appraiser, just a butcher, baker, candlestick maker-type approach and walk a length of shore and just see in the different people's opinions what would be altered by this change of tidal regime, and then we can put a dollar value on it which would be fairly accurate for that length of coast and use that as an estimate to project some either dollar value of increased damage due to the storm associated with a higher tidal rate or suggest some mitigative measures which could offset some of the effects. A very important area, but one that is more complex is interaction of tidal mixing primary productivity and fisheries landing, for instance. A lot of progress has been made in recent years and a lot is being done. In fact, there's a lot of cooperation between Canadian and American institutions on this subject.

But these are complex problems that would take a longer time and certainly much more financial commitment to get answers. And even

then, I am afraid there would be those that would not be satisfied because whenever you are dealing with complex biological systems, there will always be a great deal of uncertainty with any predictions that result.

Senator MITCHELL. Thank you, Dr. Larsen. Doctor Topinka, would you comment briefly that?

Dr. TOPINKA. I can say I agree very much with what my colleague has just stated. And I would like to reemphasize in a coastal zone that I think the areas that need to be addressed to the greatest degree have to do with changes in intertidal areas. How much is going to be—how much just due to the change of inundation patterns, this what appears to be this minute 6 inch change in mean high water. What is it actually going to do? What is the change on a lowering of low water by 6 inches? What is that going to do? How much area will that affect in particular types of habitats.

We have estimations, for instances, that on the order of 4,200 acres of the terrestrial border would now be sort of claimed by the sea, claimed by new mean high water level. Well, how is this distributed? Would it be mainly in terms of salt marsh? How much beach area will that affect? Where will those areas be? And what will that—what will the consequences be to the biological population that inhabit those areas? These are all relative to just the changes in inundation patterns.

Perhaps of greater significance and this was touched on by my colleagues has to do with the ways in which that change in tidal regime is translated into changes in tidal current velocities. Tidal currents are a very important part of the energy source that derives many biological systems. We need to understand in what regions the biological productivity would be changed by a 10-percent change in tidal range. We need to know this because we are talking about not just a small area. We are talking about the entire coast of Maine, virtually the entire Gulf of Maine.

Senator MITCHELL. Thank you, Dr. Topinka. Mr. Timson.

Mr. TIMSON. In general, I would agree with your conclusion and what Drs. Larsen and Topinka said. I think this study has taken the next step beyond the Greenberg model which said it'll have these effects in the Gulf of Maine, and this study has it.

What, then, are the areas which are going to be impacted along the Maine Coast? We have identified, I think, some of those areas within my own interest on beaches, for instance. I think that it is a safe conclusion to say that beaches are going to be affected significantly. It now becomes a matter of defining how much damage will be done to property and how much change will take place because of the project. That would take several years to undertake. I think you would have to go look at it beach by beach. You would have to now recalculate the 100-year flood storm in order to determine future damage and things of that nature.

When it comes to the effects of sedimentation on navigation, I am not comfortable in saying the impacts are significant. I think there will be an impact, but it has not been defined as yet. We don't have enough information to determine whether these will be negligible, moderate, or significant.

Senator MITCHELL. Mr. Yentsch, I would like to ask you to get together with these gentlemen and any others and provide in a letter to the committee within 30 days your best estimate of the length of time needed for the kinds of studies that have been suggested here and an estimate of the cost if that is possible.

I recognize the difficulty in making any kind of an estimate, but it seems to me we're in a position now where there must be coordination of time and effort. Mr. Baker has, in a very forthcoming fashion, suggested a joint U.S.-Canadian effort to assess the environmental impact. Of course, the precommitment study, they have a 3-year timeframe.

Dr. Larsen has suggested that this type of study may take more than that, and I would like to know as best we can what we're dealing with in terms of environmental studies and what we need as part of a broader precommitment study. So I would appreciate if you would let me have that in writing within 30 days. (See p. 165.)

Let me ask you to comment briefly, Mr. Yentsch, on two other subjects. First, I understand your wife is a foremost expert on the red tide and I expect that some of that has rubbed off on you.

Mr. YENTSCH. I think it went the other way.

Senator MITCHELL. Would you comment briefly on the impact of the tides on red tide blooms. I seek your comments because this involves the harvesting of products of the sea. I have in front of me an article that appeared in the National Fisherman, entitled, "American Shad Could Be Decimated if Fundy Tidal Dam Power Is Built." I don't know if you have seen this piece. I read it yesterday. It deals with the potential destruction of the shad population as a consequence of this dam. And, in fact, it quotes some of you people. I would like it if you could comment briefly on the red tide, and the shad problem, if you're aware of it.

Mr. YENTSCH. The problem concerning red tide has to do with the small microorganism that actually resides in the Gulf of Maine in midwater depths during the summer periods. It is there right at the moment. Now, it is actually the mixing of the water column that disburses this organism and allows the organism to come in shore and be fed upon by the clams; that is, the clams would become toxic because they filter this organism out.

Now, the concern one might have with regard to induced tidal mixing would be that greater areas or more of this would be churned up into the water column and brought ashore. It is a very difficult thing to predict because it depends on the wind system and general climatic conditions at the time. But that would be one concern.

Senator MITCHELL. Do you care to commnet on the shad problem?

Mr. YENTSCH. I would like to ask Peter. He apparently knows more about the shad.

Senator MITCHELL. Comment briefly, Dr. Larsen.

Dr. LARSEN. We have not done any work on the shad ourselves because the impact on the shad is a direct onsite effect at the dam. But Dr. Dadswell, from the St. Andrews Laboratory in New Brunswick, has done a lot of work with shad, and I'm familiar with his work, so I could comment for the record on it.

As part of the early environmental studies to identify resources which might be in harm's way if tidal power went ahead in the upper

Bay of Fundy, it was discovered, and it was not previously known, that there were a number of shads swimming around in the upper Bay of Fundy. Research project was started attacking the program. As it turns out, these fish come into the Bay of Fundy to feed in the summertime as part of their 2-year life cycle and then swim back to spawn in rivers all the way from Quebec to Florida. I think the estimates are something like 30 to 40 percent of the American shad. By American shad, that is a species name, but also the shad caught in American waters spend some part of their life in the May of Fundy.

There is concern because of their habits of swimming into every cove along the way following the shore that they will have to pass through the turbines in the tidal dams. Dr. Dadswell has calculated—I want to be careful to point out that this is his work and not by own; I do have some manuscripts of his that I could submit in testimony—he has calculated that on each passthrough of a population of shad, of about 5-percent mortality will be incurred due to damage to the turbine blades. He has also calculated because of interaction of shads' rate of swimming and the tidal currents, it is sort of three steps forward and two back for the shad on every tidal cycle that on the passage through the Bay of Fundy, eight passes will be made through the turbines by an individual fish. And if each time that fish is subjected to a 5-percent risk, you might expect a 40-percent mortality of shad passing through the Bay of Fundy.

Senator MITCHELL. Thank you very much, Dr. Larsen.

Mr. YENTSCH. Senator, one brief comment. The question has come up time and time again about the validity of David Greenberg's model, and fortunately today, we have satellites by which we can see surface temperatures over the entire Gulf of Maine almost instantaneously. And the pattern of sea surface temperature which would be predicted by David's model is there, and so one has to really assume that the model is telling us something verry realistic. So I hope you use your influence with people at NOAA and NASAR about keeping the satellites there because they are proving to be very, very useful in resolving these kinds of problems.

Senator MITCHELL. Those are the ones the administration wants to sell to a private company?

Mr. YENISCH. Or drop.

Senator MITCHELL. Well, do you agree that in view of the magnitude of the project being considered and its potential effects, and in view of the truly fundamental aspect of the conclusion that Dr. Greenberg reached regarding the effect on the tides, that it would be useful to have an independent analysis done to confirm his model?

All of the effects that you gentlemen have described are based on the assumption that the tides would be affected in this manner. And you are talking about a project of enormous magnitude with potentially very great benefits for many people.

I have the greatest confidence in Dr. Greenberg, but it seems to me that it would be useful in view of the magnitude of the interests involved to have somebody else do the same thing in whatever manner they want because these mathematical models are very complex. Like so many other things in life, what comes out depends on what goes in. Do you have any disagreement on that?

Mr. YENISCH. No, I would hope to encourage Dr. Greenberg to tighten the grid on this model. At the moment it is a very coarse grid, and we would—biologists and chemists that are interested in this problem would like to see the grid tightened so that you would have a finer resolution over the ground surface. But I think it would be dangerous just to have someone chosen willy-nilly to apply a numerical model to that situation at the moment. The person should be really a bona fide oceanographer with oceanographic background in that area, and I think that is what Dr. Greenberg has told you.

Senator MITCHELL. It is true, and I don't suggest, of course, that it be done in any willy-nilly fashion or otherwise but my judgment is that it would be useful in view of the enormous magnitude and potential benefits and because we are resting many of the conclusions that you gentlemen have reached on that keystone. It seems to me that ought to be verified before we make any final judgments on this matter, and I think Mr. Baker and his people would probably find that useful as well.

I thank you very much. I look forward to hearing from you further on the studies.

The next panel will consist of Ms. Alison Rieser, director of the Marine Law Institute, University of Maine School of Law, and Dr. Judith Spiller of the University of New Hampshire. We thank you very much for coming today and look forward to your statement. Ms. Rieser.

STATEMENT OF ALISON RIESER, DIRECTOR, MARINE LAW INSTITUTE, UNIVERSITY OF MAINE SCHOOL OF LAW

Ms. REISER. Thank you, Mr. Chairman. I am Alison Rieser, director of the Marine Law Institute of the University of Maine, School of Law, and the University of Southern Maine, Center for Research and Advanced Study in Portland, Maine.

The institute has for the last year been engaged in a cooperative research project with the complex system research center of the University of New Hampshire and with Dalhousie University ocean studies programme of Halifax, Nova Scotia. The purpose of the study is to investigate international and intertidal environmental risks of coastal energy development in the Gulf of Maine-Bay of Fundy region. Funding for the American research has been provided by the William H. Donner Foundation of New York City which has a special interest in issues of significance to both the United States and Canada and to the relationship between the two countries.

With me today is Dr. Judith Spiller of the University of New Hampshire, my colleague on the Donner research project.

The Province of Nova Scotia and the States of Maine and New Hampshire share the Gulf of Maine-Bay of Fundy system as a common resource and coastal boundary that serves as our laboratory for investigating ocean policy issues of interest to all three institutions. The Gulf of Maine-Bay of Fundy region constitutes an interrelated highly dynamic marine system where resource uses or activities in one location are likely to affect uses and activities elsewhere in the system.

Present difficulties between the United States and Canada in achieving joint or cooperative management of resources in this region are

reflected in the referral of the Gulf of Maine marine boundary limitation to the International Court of Justice in disagreements over the allocation and management of transboundary fish stocks and in the conflict over oil tanker passage through Canadian waters to the once proposed Pittston oil refinery at Eastport, Maine.

I would like to point out that some of our additional research in this area has concerned the environmental effects of offshore exploratory drilling on Georges Bank on the effects on the productive fishing grounds of Georges Bank, some of which we did under contract to the State planning office.

Law and policy in the area of national responsibility regarding prevention of transboundary environmental effects are not well developed, even for the more traditional kinds of environmental impact such as air or water pollution as we are seeing in the case of acid rain. The Fundy tidal power proposal represents a new class of environmental questions. It provides an excellent opportunity to examine the special problems that arise when a complex environmental system shared by two countries is the environmental medium of concern and where the environmental impacts are highly uncertain and indirect in nature.

My remarks are going to address the opportunities for assessing the transboundary environmental effects of tidal power within the existing frameworks of international law, domestic law in the United States and Canada and our bilateral relationship through the International Joint Commission.

I will offer some recommendations for improving our resource management capabilities for transboundary areas. Dr. Spiller will then address some of the problems confronting decisionmakers for Fundy tidal power due to the nature of the underlying scientific information.

International law currently imposes upon each nation the obligation not to use or permit the use of its territory in a manner which causes environmental damage to another nation. Alternatively, it can be said that international law recognizes the right of a nation to be free of transboundary environmental damage. The United States and Canada through their word and actions have indicated their agreement with this statement of the law. For example, a restatement of these principles embodied in the Stockholm Declaration of the 1972 U.N. Conference on the Human Environment was explicitly endorsed by United States and Canadian officials in a joint communique.

While a nation's substantive environmental rights are triggered by the breach of this obligation, international law is less clear on the responsibility of the nation creating potential environmental injury to prevent that damage from occurring. A number of sources described procedural obligation on the part of the acting country to notify and consult with the threatened country as a means of preventing transboundary damage. The United States and Canada appear to recognize at least an obligation to inform the other of projects with potential for environmental injury. The parameters of notification duty are uncertain, however, at best amounting to a moral or political duty to respond to requests for information.

I would like to point out, however, that the law in this area is under development and these considerations are changing. United States-Canada practice is even less clear on the duty of consultation; that is, the duty to discuss proposed activities with a view toward modifying

the proposal to accommodate the interests of the potentially effected country. Although as members of the organization for economic cooperation and development, both the United States and Canada have agreed in principle to engage in consultation.

Senator MITCHELL. Not working too well on acid rain right now.

Ms. RIESER. On the State-Provincial level, the Governors of the New England States and the Premiers of the eastern Provinces of Canada have recognized the importance of prior notice and consultation concerning energy projects with potential for transboundary impacts. In an energy resolution adopted in August of 1973, a permanent joint committee of the Conference of New England Governors and eastern Premiers agreed to exchange information relating to all types of energy supplies and energy needs in both regions on a continuing basis and regarding environmental problems and the ways in which they may be minimized. However, absent clear evidence of the positions of the United States and Canadian National Government, it must be said that international law does not currently appear to offer before the fact protections adequate to prevent the occurrence of transboundary environmental damages.

In the United States, and in Canada, domestic legislation provides for environmental review of certain projects, but these legislative enactments do not appear adequate to address transboundary impacts of Fundy tidal power. I would like to clarify in the United States, environmental impact assessment process is based on statute; whereas, in Canada it is a matter of Cabinet directive and is not statutory. It is uncertain whether the involvement of the U.S. utilities in Fundy tidal power would be subject to the requirements of our own NEPA statute. Similarly, it is uncertain whether the Canadian environment review process would, in fact, include adequate review of transboundary impacts.

Existing U.S. environmental review of the U.S. utility participation in Fundy tidal power would be via the Presidential permit process which is required and carried out by the U.S. Department of Energy for a transboundary to transmission lines. While environmental impact statements are commonly prepared for such lines, there is a real question whether such a statement would be required to investigate the impacts of the tidal power project itself which supplies the power to be carried by the lines. This uncertainty exists even though the current proposal as we have heard this morning is to export 90 percent of the power produced by the Fundy tidal power project to New England and New York and fundings provided by the U.S. utilities may be an economic prerequisite to the development of the project. In general, regulation of power exports is much more pervasive in the United States than regulation of power imports. We recommend that Congress consider the need for legislation assuring that the full policy implications including the environmental impacts are considered before a utility can enter into a contract for energy imports.

Senator MITCHELL. Having made those recommendations, would you write me a letter within 30 days telling me how you think that could be done?

Ms. RIESER. I would be happy to. (See p. 223.)

Senator MITCHELL. Thank you, Ms. Rieser.

Ms. RIESER. The general accounting office——

Senator MITCHELL. I mean proposing specific legislation.

Ms. RIESER. The GAO took a similar position in its September 1982, report where it specifically recommended that the Secretary of Energy work with the executive subcabinet working group on regulation, competition, and efficiency in the electric utility to establish clear Federal policy guidelines toward Canadian power imports. We agree with the GAO that the national energy policy should be examined and the existing Presidential permit process is deficient in operation because it lacks an explicit policy basis. However, we also found the GAO report deficient in its failure to give sufficient consideration to potential transboundary environmental effects of the energy facilities themselves. It failed to mention possible transboundary environmental problems, although it touched on environmental impacts and raised questions concerning such issues as energy security and national security concerns.

Fundy tidal power presents a clear example of the cases where the full pictures needs to be examined, not only the question of imported power versus domestic production but also the impacts within the United States of the energy facility itself.

State environmental regulations similarly appears not to extend to the environmental impacts of extraterritorial activity. For example, State environmental review pursuant to Maine's site location of the development act is untested as a forum for investigation of the impacts of a project where only the powerlines would be cited in Maine.

Failure to exercise controls over energy import activities by U.S. utilities in addition to failing to prevent possible environmental damage in the United States could affect the U.S. exercise of its right to be free of transboundary injury. Under existing and developing theories of international law, the failure to regulate foreign activities of domestic entities which the United States knows or should know could result in environmental damage in the United States could result in the United States being held to have consent to the production of such damage and the waiving of the right to compensation.

In Canada, it is important to note that although the Fundy Tidal Power Corp. and the Nova Scotia Power Corp. have made a commitment to submit to full environmental review under the Canadian environmental review process because of the corporation's status as a Crown corporation, its participation is not mandated but is, in fact, voluntary.

It also appears that opportunities for U.S. participation in the Canadian environmental impact assessment process either by government officials or by individual citizens would be at the discretion of the Federal and provincial officials conducting the reviews. The scope of review and the weight to be given transboundary effects is uncertain.

For example, and we have only a few examples of the environmental assessment review process working in the area of transboundary environmental concerns. But one such project would be the guidelines that were prepared for the environmental assessment review process for the Beaufort Sea hydrocarbon production proposal which is an area off the coast of Alaska and northwestern Canada. And these guidelines provided for consideration of potentially significant en-

vironmental effects in the coastal waters of Alaska and Greenland but noted that possible effects in these areas cannot be examined by the panel to the same degree of detail as those defects occurring inside Canadian jurisdiction. We are concerned that this indicates that the environmental assessment review process may have some inherent limitations when it comes to transboundary considerations. The quality—further the quality of environmental assessment review in Canada cannot as under our legal process be tested in the courts.

I would also like to point out just in passing there are a number of other authorities in Canada that may have application to this question including review by the National Energy Board, review under the Federal Fisheries Act which gives the Federal Government substantial authority to act when fishery resources are potentially threatened. And there are provincial laws and regulations that call for environmental review.

I would like to point out, however, that the area of Federal and provincial authority over environmental questions, particularly in the fishery area is somewhat controversial as it is in the United States. And that issue may, in fact, surface in the consideration of Fundy tidal power.

Most importantly I would like to discuss one existing mechanism that exists for bilateral consideration of the environmental consequences of Fundy tidal power. One mechanism would be if both countries chose to utilize it would be the reference process by the International Joint Commission which is authorized by article IX of the Boundary Waters Treaty of 1909. The two-stage reference process has the advantage of developing agreed upon scientific data base, specifically concerned with the transboundary impacts and jointly produced by experts from both countries and of providing for preparation of policy recommendations on the basis of this data by an impartial bilateral body.

The Commission has handled references in the past concerning transboundary impacts in projects as complex as the present one and with data analyses similarly as sophisticated as that required here. In particular, references have involved prediction of transboundary impacts on the basis of computer modeling just as would be involved in any reference in Fundy tidal power. The IJC functions as well when called upon to consider an existing body of scientific and technical information and to make judgments about what information is most relevant to the question of environmental impact. This ability is particularly valuable when complex systems such as the Gulf of Maine-Bay of Fundy region are involved.

Recent examination of the functions of the reference process was in the case of the highly controversial Garrison diversion unit. Garrison is a large irrigation project being developed by the Bureau of Reclamation in North Dakota. This project spawned concern in Canada that the project would cause water quantity and quality problems in Manitoba. And as a result of its potential interbasin transfer of fish species, diseases, parasites would damage important recreational and commercial fisheries.

On the basis of the IJC's international study board's scientific investigations, the Commission recommended that those portions of

Garrison which would potentially impact Canadian water quality not be constructed. Although the Commission's recommendations were strongly criticized by Garrison's supporters, the study board's scientific analysis has served as the basis for bilateral negotiations. At present, the United States has decided to modify the project to accommodate many of the concerns raised by the Commission and has revised the construction plans to postpone the development pending completion of discussions with Canada of those portions of the project which would affect Canadian water quality. Perhaps more relevant as an example would be the International Joint Commission actions in the question of Great Lakes water quality where the Commission undertook an investigation of the problems of water pollution in the Great Lakes, made recommendations that led to two significant new treaties between the United States and Canada providing for the mutual abatement of pollution in the Great Lakes and gives the IJC a continuing oversight function revealing the implementation of the water quality agreements.

Senator MITCHELL. Let me interrupt you for a second. Mr. Baker is still here. Mr. Baker, have you previously given any thought to a reference to the IJC as suggested by Ms. Reiser? You had suggested some joint efforts by the United States and Canada, and I wonder if your thoughts had progressed to the point where you considered the IJC or had thought that the joint effort should be conducted by a separate entity?

Mr. BAKER. We had considered it, Mr. Chairman, only in the context of an example, of an existing idea for such a purpose.

Senator MITCHELL. You haven't ruled it out in any way?

Mr. BAKER. We have not ruled it out in any way. Nor have we come to any judgment in our own mind as to its suitability for this particular application.

Senator MITCHELL. The advantage, of course, would be, Mr. Baker, that the IJC is an existing mechanism that has been utilized in comparable fashion previously. Human nature being what it is, it is always easier to get something going with an existing mechanism than to create a new mechanism. I am sure you thought of that?

Mr. BAKER. Yes, indeed.

Senator MITCHELL. That is something I think, Mr. Baker, we'll want to discuss further with you. We will want to determine how best to implement this common desire.

Could you sum up fairly quickly?

Ms. REISER. I would like to point out that the IJC has, in fact, had a reference on the question of tidal power in the past when the U.S. and Canadian interests were considering Passamaquoddy Bay region. I believe a reference in this area could build upon past experience. We have a few recommendations concerning institutional arrangements for examining transboundary environmental impacts. We consider that it would be important in the United States for Federal legislation to be considered to require a license for power imports and to require the conditioning of licenses on arrangements to protect the U.S. environmental interests. And we believe that this legislation should make explicit the requirement that the EIS consider impacts on both sides of the international boundary.

Senator MITCHELL. Could the United States tell an American utility that it couldn't buy power from a foreign country if that project had adverse environmental impacts in that other country alone even though that country had decided they wanted to build it?

Ms. RIESER. No, I don't think that would be appropriate. I believe considering the impacts on both sides of the transboundary area would aid in the assessment of the total costs and benefits of the project.

Senator MITCHELL. But if Canada wants to build a project and they decide that, as a sovereign independent nation, they will accept certain environmental damage in the tradeoff for whatever benefits result, it doesn't seem to me that we have the authority then to say that we don't like what Canada is doing in Canada, assuming there is no effect in this country. This is different from the current project because we could say we won't buy this power because we don't like the environmental damage in Nova Scotia and Brunswick. And you are not suggesting that by this statement?

Ms. RIESER. No, I am not suggesting that, although in this area, impacts on the environment are generally not confined to one jurisdictional area. And I think that if the impacts were primarily in another jurisdiction but one could point to the effects on the region as a whole, it would give us such authority to take action.

Senator MITCHELL. I agree with you on that, and that is what we are talking about here. Since you are providing draft legislation, I thought I would give you some guidance.

Ms. RIESER. Thank you. We believe that the CEQ regulations on environmental impact statements should also be amended to define transboundary regions and to require consideration of the effects of the Federal actions across the boundary, including such effects as long-range or indirect impacts. And that if this transboundary region section of the regulations were triggered, that special procedures for intergovernmental consultation should be specified and required.

We believe that the Canadian environmental assessment review process could be benefited by the compilation of generic guidelines establishing the same kind of mechanisms. Bilaterally, we believe that the U.S. administration should be urged to enter into negotiations with the Canadian Government toward the submission to the IJC of a reference on the transboundary implications of the Fundy tidal power project. And the reports of the IJC and its study boards, along with recommendations, could be incorporated into any environmental impact statement or any assessment prepared and serve as one of the alternative courses of action explored in the impact statement.

Finally, we believe that both sides should take the opportunities presented by Fundy tidal power to make explicit their belief that the two countries are bound by international law obligations, to notify and consult on projects with potential transboundary impacts and to specify the procedures to be followed in such cases. Thank you, Mr. Chairman.

Senator MITCHELL. Thank you. In view of the manner in which the U.S. Government is now ignoring its obligation under that same law with respect to acid rain, Canadians could be pardoned for taking that with a grain of salt, but I think it is a very wise suggestion.

Dr. Spiller, we look forward to hearing from you. Because we are now down to 1 hour, and we have four witnesses after this panel, I would ask if you could summarize your statement within 10 minutes.

STATEMENT OF DR. JUDITH SPILLER, ASSISTANT PROFESSOR OF RESEARCH, COMPLEX SYSTEMS RESEARCH CENTER, UNIVERSITY OF NEW HAMPSHIRE

Dr. SPILLER. Mr. Chairman, I am Judith Spiller. I hold a Ph. D. in earth and space sciences and am currently an assistant professor at the Complex Systems Research Center at the University of New Hampshire where my research specialty is the application of marine science to environmental issues.

I wish to address my remarks to some of the constraints concerning predicting of the transboundary effects of Fundy tidal power and to whether the existing body of scientific information is sufficient to evaluate the project's risks. Let me start by stating that to extrapolate effects from the model developed by Dr. Greenberg with that considering the role of intervening factors including such things as the shape of the coastline, ocean basin, topography, meteorological effects, and other astronomical influences is scientifically unsound.

Our research indicates that these factors may moderate the changes predicted by the Greenberg model but our understanding of the behavior of the forces which structure the Bay of Fundy and the Gulf of Maine system is too limited to make predictions with any surety. In fact, we suspect that the number of steps between the amplitude changes suggested by the Greenberg model and their expression is damage to coastal property, for alterations in fishery productivity argue that the risks associated with Fundy tidal power are relatively small. And they will be lost in the noise of the gulf and the bay system. Faced with the model which presents in the form of numbers its amplitude, as does the Greenberg model, a temptation exists to translate those numbers directly into quantitative changes. This approach establishes worst-case scenarios. In this instance, it assumes a change in amplitude in the model boundary will be translated directly into substantial higher tides. This approach minimizes the caveats, those intervening factors that I mentioned.

Further, this worse case approach when conducted without the benefit of peer review provides a distorted and oversimplified view to the public and often polarizes an opinion making a balance review of costs and benefits of the project impossible.

In our review, we have sought to move away from the worse case approach. Rather we have examined the Fundy tidal power project as operated under interdependent interactive systems and have attempted to evaluate scientific information on that system.

Our research indicates that scientific investigations growing primarily from work of the Fundy environmental study committee adequately addresses the issue of near-field effects. The same sufficiency does not apply to questions about far-field transboundary effects. However, we feel as I will discuss that the extensive research program directed specifically at collecting new information concerning the effects

of Fundy tidal power will yield little because of the highly dynamic nature of the Gulf of Maine, Bay of Fundy region.

Senator MITCHELL. Would you say that again? You think studies will yield little because of the highly dynamic nature of the region?

Dr. SPILLER. That's right. Studies directed directly at Fundy tidal power. Rather we think that research effort should be directed at understanding the overall details of the system rather than looking at this one particular issue.

Senator MITCHELL. If someone proposes to build a specific dam at a specific site though, wouldn't prudence dictate at least an attempt to evaluate the consequence of that?

Dr. SPILLER. I think we have seen, and we have heard today attempts at making those evaluations. I think that we have a fairly large body of information about the behavior of this region. It is true, it is a very general picture and because of the complexity of the region, it is very hard to predict with any exactitude how the system is going to respond to perturbation.

Now, we recommend that more research be directed in this area looking at response to perturbation. We think that research that would be directed specifically at looking at the effects of Fundy tidal power on the coastline and on the fisheries productivity would yield the picture that is very similar to what we now have and would not improve our predictive power.

Senator MITCHELL. Are the two mutually exclusive, Dr. Spiller?

Dr. SPILLER. Yes, I think they are. And I think that I can clarify that by saying what we suggest is that taking advantage of the IOC mechanism which empanels a group of scientific experts to review existing information that a good job of evaluating that information and assessing the uncertainties associated with any predictions that would be made about an activity like Fundy tidal power would result.

Rather than spending more money on conducting new scientific research, we would like to see experts in the area brought together and have them address the issues and perhaps they would recommend new studies. We don't exclude that possibility. But we would prefer to see that done as the result of in a sense consensus among people who were currently conducting research on the behavior of this region and in a bilateral context.

This sort of panel also serves the function of peer review which is often also when scientists are catapulted into a public policy domain and make statements like the statements we have all been making today.

Well, I will move to discussing the constraints involved in making predictions about the effects of Fundy tidal power. And I will start by assuming that the principal effect of the projected changes will either be on coastal property, and we have heard in some detail speculation on those changes, and on fisheries resources because of changes in the mixing characteristics in this region.

In order to predict these effects, it is necessary first that the changes be detectible, that is measurably different from what has been observed in the past; and further that these changes be attributable to the presence of the tidal power barriers in the upper regions of the Bay of Fundy. Attribution and detection essentially establish causal-

ity and require the speculated changes from tidal power development be either unique or significantly greater than those observed for existing phenomenon.

It's generally agreed that changes in tidal amplitude will shift physical and biological parameters but some of these shifts occur already. For example, storms commonly raise water levels along the coast, causing varying degrees of destruction and fisheries abundances, commercial species like herring and sea scallops may exhibit dramatic year to year differences in abundances. Finally, astronomical and meterological forces, the degree of solar radiation, the rotation of the earth and the basic topography of the Bay of Fundy and the Gulf of Maine all structure the hydrodynamics of the Bay-Gulf system. And, in turn, influence biological productivity. Thus, these changes are changes in magnitude rather than in effect and so are not unique. The Fundy tidal power project may, in fact, increase storm damage and alter productivity. But whether or not these increases will exceed the natural range of variation in the physical system represents an important question. Changes in both characterize dynamic ecosystems like that in the bay and the gulf under normal, average condition. Some consideration of the many factors influencing the bay and gulf systems suggest that the wide range of variability commonly encountered here and place perspective on the changes projected for the tidal power project.

If, for example, we assume as Dr. Greenberg's model predicts that a 30-centimeter increase in tides will occur along parts of the coast of Maine, would we then conclude that the increase would be manifested as a 15-centimeter higher high tide and a 15-centimeter lower low tide in the intertidal region. To reach this conclusion, factors contributing to the level of the sea must be considered. In addition, to the lunar tidal effects—the M2 tide—numerous other astronomical forces operate to magnify or diminish tidal height. Although the effects of these forces are relatively small compared with the M2 tide. Further, as I mentioned, coastal configuration and bottom topography also act to dissipate tidal energy. We have heard earlier of the contribution of the rise in sea level to this issue.

Finally, meteorological forces also exert a strong influence on sea level. Prevailing winds in conjunction with coastal configuration effect tidal height and current strength. Storms, however, are a dominant influence. Strong winds blowing toward land can create frictional stresses on the water column. The result of storm surges that cause coastal damage associated with large storms. These storms can build waves up to 10 feet as we experience the 1978, above sea level for 100-year storm. The passage of a major storm low-pressure center also increases nontidal sea level and this can be as much as 0.6 meters.

Consequently, a 15-centimeter increase in tidal height must be evaluated against the contribution of sea level of each of the proceeding. While such an increase would enhance the wave height of a 100-year storm roughly 10 percent, this change would be tempered by the direction, the intensity and the speed of onset of storm conditions. Thus, several factors whose behavior we only crudely understand contributes to enhancing or diminishing the contribution of Fundy tidal power of sea level along the coast.

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Predicting actual coastal effects, that is the degree of erosion and flushing is similarly confounded. While we can, with some accuracy, predict beach erosion, given the inclination of the beach, its composition, and angle of wave attack, the intervening factors mentioned above, coastal configuration, bottom topography, prevailing wind, direction, intensity and duration of storms all play significant roles and are not quantifiable. Each will influence the total centimeter—30-centimeter tidal range change before that change is translated into intertidal effects.

Assessing the changes in mixing on fishery resource is more difficult still. Areas of turbulent mixing such as the zones of contact between the Gulf of Maine and the Bay of Fundy water masses or along the coastline correlate with areas of high biological productivity. In such areas, upwelling brings nutrients to the surface and mixing distributes oxygen in the water column and contributes to more uniform temperatures. In shallow waters tidal movement aids this—tidal movement aids this mixing. A broader tidal range will increase the zones for areas of tidal mixing in shallow waters. It is predicted that it will. These zones particularly around Grand Manan Island southwestern Nova Scotia appear to serve as areas for the aggregation of prespawning herring. Larval, juvenile and adult herring also may follow the residual circulation pattern as they move around the Bay of Fundy and the Gulf of Maine.

Senator MITCHELL. Dr. Spiller, I don't want to interrupt you, but we have only about 40 minutes remaining. We have four more witnesses. Can you sum up in a minute or so. I want to give everybody a chance to be heard.

Dr. SPILLER. What effect the Fundy tidal project will have on these phenomena remains unclear. But an important point to note is that for fisheries—issues of fisheries abundance, Canadian resources will be affected similarly by the changes resulting from Fundy tidal power as will United States resources. If the Canadian Environment Review Process operates properly, it will evaluate the effect of Fundy tidal power, no reason to suspect that it won't, it will evaluate the effect of Fundy tidal power on these and other resources as well as on coastal property and structures. Indirectly the resources important to the United States will be considered.

Neither of these—the above discussion doesn't answer the question of whether or not Fundy tidal power effects will exceed the natural variation of the region or whether the changes will be beneficial or harmful.

There is a suggestion that the range of expression of environmental factors that work in the Bay and Gulf system that there is this range, and these factors may magnify or block each other in ways we have difficulty in predicting. These interactions also suggest that an extensive research program directed specifically at evaluating the effects on tidal power will yield little more information primarily because of our basic understanding which is really only a general picture of the system. Rather, any available research finds should be directed toward further understanding the fundamental mechanics of the basic system.

Finally, our review of scientific research suggests that the decisions concerning proceeding with the project should start by assuming that

some damage may occur, although perhaps only localized in extent. Given this assumption, then a cautious appraisal of the environmental benefits and costs of Fundy tidal power should proceed. Thank you.

Senator MITCHELL. Thank you very much, both Dr. Spiller and Ms. Reiser. I emphasize that your prepared statements will be placed in the record. I appreciate your summarizing them. I thank you both very much for your testimony. Dr. Spiller, if you wish to submit in writing a statement of the kind I asked of Mr. Yentsch of the Bigelow Labs, I would welcome receiving that as well. I would welcome your thoughts on the type of study on the length, and on the estimated cost.

Dr. SPILLER. Fine. (See p. 248.)

Senator MITCHELL. Thank you. In view of the fact we have about 40 minutes and four more witnesses, although it was not intended that the final four witnesses appear together, I would like to ask them if they would all come to the table. Commissioner Apollonio, Mr. Otness, Mr. Ishkanian and Colonel Sciple. I want to make certain that everyone who has been asked to come here gets the opportunity to be heard. I would like to suggest that each of you limit your remarks to 10 minutes or less so that no one is left out. I will have to start being a little more forceful about limiting time. Why don't we begin by welcoming a very able and effective commissioner of the Maine Department of Marine Resources, Mr. Spencer Apollonio.

STATEMENT OF SPENCER APOLLONIO, COMMISSIONER, MAINE DEPARTMENT OF MARINE RESOURCES

Mr. APOLLONIO. Thank you, Senator Mitchell. I will be as brief as I can. The first issue of shad has been raised at this hearing, and I would like to introduce a letter from the Atlantic States Marine Fisheries Commission, which arrived on my desk this morning. It discusses exactly that issue. It is very timely, and your staff will receive a copy of that letter.

Senator MITCHELL. Thank you. It will be made a part of the record of this hearing. (See p. 253.)

Mr. APOLLONIO. I am simply going to read one page of my statement because I think it gets to the problem. And it starts at the bottom of page 2. In essence, this hearing is asking questions concerning the fisheries resources, and I would emphasize that I am now talking about the offshore fisheries resources, not the intertidal shellfish resources. The hearing is asking questions that cannot be answered by the existing state of fishery science just as analysis of fishery management issues is restrained by the rather primitive state of fishery science. This hearing seeks to learn what research project should be undertaken to better define the probable impacts of the Fundy tidal power project on the fisheries. The point I wish to emphasize is that at this time we lack the fundamental scientific understanding of how fish ecosystems work and how fish species singularly and in aggregate interact with their environment to be able to make the suggestions that the hearing seeks to obtain. In short, we are suffering from a lack of basic ecosystems research.

Why is this so? Very simply, I believe, in large part it is because funding for fishery science has been rigidly compartmentalized. Scientists recognize the need, but the general administration of funds

is not responsive to the need. The agencies that support research and basic principals of ecosystem interactions, quote, do not do fish, end quote. And the agencies responsible for fisheries are generally so pressed for immediate answers to immediate problems that they have little reserve capacity to address fundamental long-term research problems. Thus, as a result, no one is developing the basic scientific concepts of the method that should be applied to the issues raised by the Fundy project. As a result of that lack of basic research, we have to say we don't know. Furthermore, we are not even sure how to find out.

The Congress is considering the possibility of establishing the National Oceanic and Atmospheric as an independent agency now. The discussion also, I believe, involves whether the National Marine Fishery Service should remain within NOAA or be transferred to a department. I would recommend that the National Marine Fishery Service stay within NOAA. That arrangement holds the most promise of the kinds of fundamental research that is clearly needed in the case of this kind would, in fact, be taken—undertaken. The Nation's fisheries research agency would be operating within the context of the Nation's systems research into the oceanic and atmospheric interactions, and that is exactly the context in which fishery science should be pursued, and it is only within that context we are able to give you answers to the kinds of questions you're seeking today. Thank you, Senator.

Senator MITCHELL. Thank you, Commissioner. We will hear now from Mr. Phillip Otness, the executive director of New England Power Pool.

STATEMENT OF PHILLIP C. OTNESS, EXECUTIVE DIRECTOR, NEW ENGLAND POWER POOL

Mr. OTNESS. Good afternoon, Mr. Chairman. My name is Phillip Otness. I am the executive director of the New England Power Pool located in West Springfield, Mass. I am pleased to be able to present testimony to your committee concerning the planning and capacity needs of the New England utility. In 1971, the utilities formed the New England Power Pool. The objectives of the NEPOOL are reliability, economy, and equitable sharing of benefits. The NEPOOL system includes over 91½ percent of the New England electric generation and load is operated as a single electric system. Bulk of the remaining load is located in northern Maine and is electrically remote from our system. That load is however, interconnected with the New Brunswick Electric power commission system. The NEPOOL system is interconnected with the New Brunswick system to the northeast and to the New York Power Pool to the west. Planning is well underway and contractual commitments have been executed for an interconnection with the Hydro-Quebec system scheduled for operation in 1987. There are approximately 85 individual companies represented by about 45 NEPOOL members. The members generating needs vary in size from approximately 2 megawatts to as much as 4,700 megawatts and generating units in size from less than a megawatt to 864 megawatts.

The NEPOOL staff provides the following services for the system and all of its members: Long-range forecasting of electrical peak load

and energy, generation and transmission planning, guidelines for reliable and economic system expansion, minute-to-minute operation and dispatch of all generation and major transmission, accurate billing for all pool transactions.

The concept of NEPOOL is to operate all facilities without regard to ownership, thereby assuring the load total cost of New England consumers. In 1982, NEPOOL savings reached $62,000,000 in which 17,000,000 were generated from transactions with New Brunswick and New York. The 3.7 million megawatt hours of energy purchased from these neighboring pools displaced 6.4 million barrels of oil in New England.

The highest peak load that New England ever experienced was 15,702 megawatts in January 1982, while the highest summer peak was 15,400 megawatts in July 1982. Over the 1963 to 1972 period, the New England average compound load growth was 7½ percent, and had this continued, we would have experienced that peak in 1974. The actual average compound load growth over the 1973 to 1982 period was about 1.9 percent. This loss of the equivalent of 10 years load growth is an illustration of the effects of the oil embargo, conservation, and the resulting economic recession during the last decade which is continuing to some extent today.

Price induced conservation by residential, commercial, and industrial customers since 1974 has significantly impacted load growth and eliminated the need to install approximately 10,000 megawatts of generating capacity. Load management by the NEPOOL company has also drastically affected the load level. Reflected in our current load forecast is more than 1,000 megawatts of load management by the year 2000.

The current forecast for electrical load growth through the year 2000 calls for an average annual compound growth of about 1.8 percent for both winter and summer and 2.2 percent for energy. Based on NEPOOL's present schedule of additions, purchases, and retirement, it is expected that adequate reserves to serve the forecasted load and provide for unforseen contingencies will be available to 95, 96 as shown in table 1. Beyond that year, we project we will require additional resources of about 2,000 megawatts to adequately meet the needs through the end of the century.

The energy forecast and source of supply by fuel types is shown in table 2. No major generation is being actively pursued for completion in the 1990's, although several potential projects are under consideration.

Our goal in New England for the last decade has been to reduce dependence on foreign oil. In 1973, 65.5 percent of the electricity was generated by oil. By 1980 we reduced it to 55.6 percent. In 1982 further reduced it to 39.8 percent. Exhibits 1 through 3 dramatically illustrates that oil generation is projected to drop to a low of about 15 percent in contribution in 1990 and subsequently increases to 28 percent by the year 2000. Therefore, we must have additional resources in the 1990's and planning must start soon if we are continuing to meet this objective.

The following NEPOOL units are under construction, Seabrook nuclear units No. 1 and No. 2, and Millstone nuclear unit No. 3. I can't

emphasize enough that they must be finished along with 1,600 megawatts of future coal conversion if we are to achieve the reduction in oil consumption highlighted in my exhibits.

I mentioned earlier our plans to complete an interconnection with Hydro-Quebec. We finished negotiations in March of this year with Hydro-Quebec, and I have given you some details on page 5. We are in negotiations now with Hydro-Quebec for phase 2 which would increase the capacity to 2,000 megawatts. We are also exploring other possible purchases which have been recently offered such as capacity for New Brunswick and coal plants in New York. New England has several potential coal plants of our own including Sears Island and Canal No. 3 project, both which could be operational by 1995.

NEPOOL will examine every possible alternative for meeting expected capacity needs during the 1990's. Alternatives include but are not limited to biomass, cogeneration, fuel cells, small hydro, trash burning, solar, wind, and advanced coal technology. These alternatives could possibly contribute as much as 1,500 megawatts of capacity through the New England system by the year 2000. They will be evaluated on their own merits, but must compete economically against the other alternatives that are available and have been cited above.

There exists in the NEPOOL system 200 megawatts of deactivated oil-fired capacity that could be returned to service if needed and the existing NEPOOL generating unit retirement plans include an additional 1,900 megawatts of oil-fired generation that could be continued if necessary. However, many units will be over 50 years old by the year 2000 having long exceeded their expected useful and efficient service life.

We believe it is important to explore all opportunities for power development, especially in the Northeast area where we have been overly dependent on fossil fuel. In planning for the future, we must seek both additional resources within our own system and strong transmission interconnections with other systems. Only through strong interconnection can we take advantage of regional diversities including hydro potential weather, tides, daylight, and so on. A series of such interconnections where large movements of power can take place in a reliable manner over great distances could result in substantial savings to our customers. We encourage the committee's further study of the environmental effects of the Canadian tidal power project. We must do our homework now if we are to make the wisest choice of resources for the future.

I hope this information, Senator, will be of assistance to you and your committee. Again, I thank you for your time, and I appreciate the opportunity to be with you this afternoon.

Senatr MITCHELL. Thank you, Mr. Otness. Your comments are very useful. Mr. Ishkanian.

STATEMENT OF MARK ISHKANIAN, NATURAL RESOURCES COUNCIL OF MAINE

Mr. ISHKANIAN. I would like to thank you for the opportunity to express viewpoints of the Natural Resources Council, a private citizens conservation organization based here in Augusta.

It has been suggested to me on a number of occasions that the Fundy tidal project is Canada's means of seeking revenge upon the United States for millions of tons of sulfur dioxide we dump on eastern Canada each year in the form of acid rain. While Maine, as a victim of acid rain pollution itself can certainly sympathize with the viewpoints, we feel their efforts are somewhat misdirected. Instead of flooding the Maine coastline, they should try to raise the level of Lake Erie enough to threaten the Midwest. Then we may get somewhere in solving the acid rain problem.

On a more serious note, the council has a strong interest in the use of tidal power as an alternative energy source to reduce our dependence on fossil fuels and nuclear power. We have closely followed the developments of the Cobscook Bay and Halfmoon Cove tidal projects and maintain an open mind on these projects pending the availability of detailed environmental studies, but the magnitude of the Minas Basin project and the tremendous environmental uncertainties surrounding it cannot but help alarm conservation interests. At stake are Maine's rich coastal and marine resources—a unique part of our natural heritage and essential components of our State's economy and a way of life.

The Gulf of Maine is a vast, complex and poorly understood ecosystem. Experts here today have only been able to hint at the environmental implications of the Fundy tidal project. They readily admit the difficulty in predicting with any accuracy the full impacts of the project. It is an unfortunate dilemma of these times that our ability to manipulate the world environment is progressing at a far more rapid rate than our ability to understand the implications of these actions. Acid rain, hazardous waste, and toxic pesticides are but a few of yesterday's mistakes that we are paying for today. But even when we look at the few impacts of the Minas Basin project what we can predict today with some certainty, the council finds compelling arguments against its construction.

The devastating effect on the shad fishery that has already been mentioned and the work that Dr. Michael Dadswell has done in discovering that 10- to 40-percent mortality rate would occur with shad over 1 year and a potential 40- to 70-percent mortality rate of the shad population over a 10-year period are cause enough to look at this project seriously.

Second known impact of the Fundy project which is of great concern to the council is the inundation and accelerated erosion of Maine sand beaches and dunes. For close to a decade, the Natural Resource Council has been a strong voice advocating the wise management of our sand dune systems. We have been involved in dozens of sand dune cases before the Department and the Board of Environmental Protection.

Just a few weeks ago the State of Maine took a big step forward by implementing new regulations which will improve the protection of our sand beaches from inappropriate development. All of these gains in past years are overshadowed by the potential consequences of the Minas Basin project.

The Bigelow lab study estimates that some beaches in southern Maine would retreat as much as 60 feet and severe storms causing extensive beach erosion would be more than double in frequency.

To understand the full implications of these impacts, one must first understand our sand beaches today. These beaches, while comprising only a small fraction of the State's overall coastline, are a major recreational, economic, and ecological resource. Even now our 37 miles of sand beaches are a highly stressed ecosystem. Over 60 percent of our beaches are developed and much of this development has occured in a manner which has accelerated erosion. Each summer millions of people descend upon the beaches taking their toll on vitally important dune vegetation and critical wildlife. Increased tidal levels and storm surges created by the Fundy project will fundamentally change the character of our southern coastline, swelling up sections of beach to say nothing of the houses built upon them. This, in turn, will concentrate human pressures on the remaining sand beaches and dunes leading to increased destruction of these fragile areas.

For years we have encroached upon these fragile sand systems from the land. If we now encroach upon them from the sea, we may find little left to enjoy.

But what alarms the council most about this project is the multitude of unanswered questions and the questions which haven't even been thought of yet. Shifts in circulation patterns, decrease in surface water temperature, salt marsh flooding, climatic changes, increased red tide occurrence, and fluctuation in primary productivity are all areas of great uncertainty. How these changes go together effect the distribution and abundance of our fisheries is of utmost importance, yet it appears to be beyond the tools of modern day marine science.

Only a few pieces of the Fundy Bay tidal project puzzle are in place but already a picture of unprecedented environmental and economic destruction of our ocean and coast is appearing, understanding that many of the predicted impacts of the project are based on Dr. Greenberg's model, the council recommends further research to substantiate and refine Dr. Greenberg's work.

Additionally, we recommend that the Canadians explore other smaller scale tidal projects options whose impacts we would expect to be of smaller magnitude and less far reaching. With our experience in tidal power production still in its infancy, it seems prudent to develop several small stations and evaluate their impact prior to consideration of such a gargantuan affair as the Minas Basin.

Thank you, Senator Mitchell, for the opportunity to present the Natural Resources Council's views on the Fundy tidal project.

Senator MITCHELL. Thank you, Mr. Ishkanian.

Colonel Sciple.

STATEMENT OF COL. CARL B. SCIPLE, DIVISION ENGINEER, NEW ENGLAND DIVISION, CORPS OF ENGINEERS

Mr. SCIPLE. Senator Mitchell, I'm Carl Sciple, division engineer for the New England Division, U.S. Army Corps of Engineers. It is a pleasure to appear before your committee today to discuss the items in the Bay of Fundy. Senator Stafford asked our Chief of Engineers, General Bratton to discuss studies that have been conducted by the corps relating to tidal power development in the Bay of Fundy and the Gulf of Maine together with an outline of work still to be accomplished

by the corps. The chairman also asked a discussion of studies that should be reasonably undertaken together with the discussion of the studies that would be within the abilities of the corps to analyze the environmental impact of the proposed Canadian Bay of Fundy project in the United States.

On the first request, to save time, I would like to provide for the record a written statement discussing the corps' activities on power development in Passamaquoddy and Cobscook Bays.

Senator MITCHELL. Thank you. That will be placed in the record. (See p. 272.)

Colonel SCIPLE. Just by way of general comparison, the largest of the alternatives that the corps evaluated at Cobscock Bay would generate 790 million kilowatt-hours annually. Proposed Canadian development in Minas Basin is reported to be able to produce about 12 billion kilowatt-hours. It is a factor of about 15. That brings us to the second question that I was asked to respond to; mainly, the analysis of the environmental impacts of the proposed Canadian Bay of Fundy project on the United States.

The proposed Canadian development in the Minas Basin could create problems through an increase in tidal range extending from Maine southward to Cape Cod. It's been reported that this change in the tidal range could vary from 6 to 18 inches. If this is true, the raising of mean high water levels could seriously impact on the man-made structures along the coastal regions as a possibility of damaging the fragile natural ecosystems recently protected by the Congress when they passed their barrier island bill.

There could be a physical impact on navigation projects if the mean water levels are lowered. For instance, with the difference of 12 inches, commercial vessels which fully use the available depth would need to enter the harbor light loaded or wait for higher tides, resulting in a decrease in efficiency and an increase in cost to business and consumer alike.

There are about 125 projects of the New England Division of the Corps which could be affected by these tidal changes. In addition, State, local, and private interest have also constructed many other channels and facilities which could be affected.

A grave concern would be the impact of public and private shorefront development. Significant erosion could occur that would affect homes, cottages, hotels, and many miles of beaches.

In order to evaluate these problems, studies that should be undertaken at this time relating to the Bay of Fundy power development, should initially focus on verifying the amount of tidal surges that could be expected to occur and what natural and manmade resources could be threatened by such shifts. This means a reevaluation of the previous mathematical model which was first used to predict tidal stage changes. The Corps is a leader in tidal hydraulics and has outstanding expertise in the sophisticated state-of-the-art mathematical modeling techniques and could provide assistance in this area. Upon verification of the analytical approach used in the previous model, attention would then shift to determining the necessary environmental baseline requirement needed in the mathematical model. Information would have to be drawn not only from the Corps

and other State and local laboratories, but also from the National Marine Fisheries, NOAA, Fish and Wildlife Services and possibly EPA. This effort would have to be coordinated with the environmental offices of the maritime provinces to make available any data or inventories that may have already been completed or underway in the maritime provinces. Both New England and Canada would benefit from an examination of environmental impacts on such issues as red tide and the anadromous fish runs which currently traverse the Bay of Fundy and Gulf of Maine. If the tidal surge of 6 to 18 inches is verified, the Corps' prime concern would be the tidal impacts on Federal investment in the 125 coastal projects.

In addition, the New England States would also be concerned with the impact on their public and private investments in the area. Study efforts would be made to determine what modifications would be made to offset the impact of the tidal surge or changes in mean low water.

I believe that the Corps working with the International Joint Commission could coordinate an effort by effective State and Federal agencies and the maritime provinces to develop studies that would assess the environmental, physical, and economic impact of such a project.

Mr. Chairman, in summary, I suggest a two phase study would be a reasonable approach to a more finite determination of the proposed project's effect.

The first phase should focus on the tidal range using current state-of-the-art technology in modeling and then identifying the degree of effort required to assess the impacts upon the natural and manmade resources along the affected coastline.

If these phase 1 studies indicate there is a significant change in the tidal range, then phase 2 studies should proceed. Phase 2 studies would determine the environmental, social, and economic impacts and what measures, if any, could be taken to offset these impacts. Mr. Chairman, this concludes my statement. I will be glad to respond to questions.

Senator MITCHELL. Thank you, Colonel. Are you able now, or would you perhaps submit in writing to me in somewhat more detail the precise nature of the studies, the length of time you think they would take and how much funding would be required and which or all portions could be handled by the Corps.

I would like, in other words, to take your last paragraph in your statement and expand on that in considerable detail. We want to deal with erosion, navigation, all of the many areas that you have a great deal of your agency and you personally have a great deal of expertise in. Would you do that?

Mr. SCIPLE. Yes, I will. (See p. 278.)

Senator MITCHELL. Do you feel it would be appropriate or desirable for an entity of the U.S. Government such as the Corps to validate the Greenberg model; that is, to construct an independent model or to review the existing model or to provide a more firm basis for that model's conclusion?

Mr. SCIPLE. Yes, sir, I do. I think it would be very prudent for the United States to look at and verify that which has been suggested.

Senator MITCHELL. And is that something that is within the capacity of the Corps both from the standpoint of expertise and resources?

Mr. SCIPLE. In terms of expertise, yes. We would need resources to initiate that effort.

Senator MITCHELL. But you would be prepared to do that given the resources?

Mr. SCIPLE. Yes, sir.

Senator MITCHELL. I am very anxious to have a more detailed statement from you on the studies. We want to get as much detail on that as possible. I want to thank you all very much for your statements.

I want to ask Colonel Sciple and Mr. Otness one question which has not arisen during this hearing, and which I think relates to an important factor that we should consider. It is a little over 10 years since President Nixon announced Project Independence and established as a national goal of the United States the achieving of independence in energy. I notice a lot of statements here today have used the phrase "foreign oil" and have decried our dependence on foreign oil. There are two concepts there, one is foreign and one is oil.

What are the implications of our proceeding with respect to a project that is now envisioned to produce 12 million megawatts a year, 90 percent of which will be consumed in the United States. This figure may be compared to Maine Yankee which now produces 5 million megawatts and is considered to be a very large producer of electricity. Would such U.S. consumption of Canadian power be consistent with our national goals, as close and as friendly as our relationship is with our northern neighbor? Canada is, of course, a foreign country. Is reliance on foreign energy something we should be concerned about as a nation? Mr. Otness, this is an area where I think you would be interested in. I would like to hear your comments and then Colonel Sciple's.

Mr. OTNESS. That is a very tough question in many of our utility executives. Our concern with an overreliance on foreign country regardless of who it is or how friendly they happen to be now. In this particular project, remember that it is providing energy, and therefore it displaces foreign fuel or domestic coal, but it doesn't necessarily displace a need to build capacity in the United States. It just displaces the fuel because this is not a project that we can count on 24 hours a day. I think most of the utility industry would say a small import of power from different directions, different countries, imports of oil from Mexico and so forth is OK. But what we should never allow ourselves to do again is get too dependent on any one particular fuel or one particular country. We should have diversity.

Senator MITCHELL. In other words, we should have diversity and not dependence?

Mr. OTNESS. We are not an island in the world.

Senator MITCHELL. But the trouble is, Mr. Otness, no matter how diverse our dependence, you don't have independence if you're dependent on others?

Mr. OTNESS. That's true.

Senator MITCHELL. Subject to external manipulation, but it still does not achieve the affirmative goal of independence. Colonel Sciple.

Mr. SCIPLE. I would answer your question yes. I agree with Mr. Otness. I think it increases our flexibility, and I think it does something very positive and preserves a resource which takes a long time to renew, oil.

Senator MITCHELL. Colonel, on a separate issue, were you present when the Governor testified?

Mr. SCIPLE. Yes, sir.

Senator MITCHELL. And you're aware, are you not, of the Aroostock County irrigation project with respect to which Senator Cohen and I recently introduced legislation?

Mr. SCIPLE. Yes.

Senator MITCHELL. Does the Corps have authority to undertake such a demonstration project? Would you continue, Colonel.

Mr. SCIPLE. Sir, we do not have authority to implement that type of program, however we can provide technical assistance.

Senator MITCHELL. You can provide technical assistance?

Mr. SCIPLE. Yes, sir.

Senator MITCHELL. Do you know how much the project would cost? How long it would take? Do you have any opinion on its merits?

Mr. SCIPLE. First of all on its merits, I think it is a terrific project. It makes all sorts of sense to me. In terms of how long it would take and how much it would cost, we look at in two phases. First phase we estimate would cost about $3.4 million. It would take about 2 years. It would be a research and demonstration project.

And the second phase would build out of that first phase depending on what was found out and if it came to fruition, we would see that taking 10 years additionally, costing about $11.6 million more.

Senator MITCHELL. And can you just briefly comment on why you think it is a terriffic project, what benefits you see flowing from it?

Colonel SCIPLE. It improves water quality first of all. It minimizes a great amount of soil erosion that is occurring. It increases the yield of potato crops significantly. Those are the prime reasons, sir.

Senator MITCHELL. I want to thank you gentlemen and all of the witnesses who appeared here today for providing what I think is a good deal of information about what will undoubtedly be a very major public policy decision to be made both in Canada and in this country sometime in the reasonably near future.

It seems clear to me that we need to know much more than we know now about the project itself and the effects of the project before any decision can finally be made.

But I want to say that I am very encouraged by not only Mr. Baker's taking his time to come here but his forthcoming attitude regarding the opportunity for participation by this country in making the assessments that will be necessary. It is a sign of the long and friendly relation between our two countries.

Also thank Dr. Greenberg who I guess along with Mr. Baker came a long distance here. We are very appreciative of that.

We in the committee will be considering what steps we can take to facilitate consideration of this project, and we look forward to further hearings in the future as information becomes more available. For now, I will declare the hearing closed.

[Statements and other material submitted for the record follow:]

TESTIMONY SUBMITTED

BY GOVERNOR JOSEPH E. BRENNAN

TO THE SENATE ENVIRONMENT AND PUBLIC WORKS COMMITTEE

JULY 25, 1983

ON THE ST. JOHN RIVER BASIN RESEARCH DEMONSTRATION PROGRAM

FOR CROPLAND IRRIGATION AND CONSERVATION

THE HONORABLE GEORGE J. MITCHELL

SENATOR MITCHELL:

I would like to urge the committee to assist Maine in our efforts to implement the St. John River Basin Research-Demonstration Program for Cropland Irrigation and Conservation. Specifically, I would recommend that you request Colonel Sciple, Division Engineer for the New England division of the Army Corps, to prepare a funding schedule for implementing this important program. I further recommend that the committee act favorably and promptly on the authorization bill for this project, S1669.

The St. John River Basin in Northern Maine represents the largest area of contiguous cropland in New England, comprising over 12 percent of the prime agricultural land in production. Farms in the basin are the major supplier of seed potatoes for the Eastern United States. However, the potato industry in Maine is in trouble. There are many complex reasons for the difficulties facing this industry.

Its problems must be addressed if it is to continue as a major industry for Maine as a whole and as the economic foundation for northern Maine.

While the average yields of potatoes per acre have increased 48 percent in the west, there has been an 8 percent decline in Maine, in the last 20 years. The graphs attached to this testimony show a steady decline in total production, acres in production and yields per acre.

This decline has contributed to the depression in the economy of the area. People have had to leave the region over the years to find jobs elsewhere. The unemployment rate in the region was 14 percent this past May, 4 percent above the national average.

The proposed St. John River Basin Project promises relief from these circumstances. It is designed to act as a catalyst by demonstrating to farmers sound practices that will conserve soil and increase production.

The Corps study projects that irrigation coupled with improved conservation practices could increase yields per acre by as much as 65%. In addition, the Corps study predicts that the project will revitalize the soil and reduce erosion of our prime farmlands. According to Corps'estimates combined irrigation and conservation measures would aid the environment

by effecting the following reductions: 59 percent in erosion and sediment loadings in streams; 62 percent in biocide loadings; and 46 percent in nutrient loads. It will help put farms in the region back on a firm economic footing, and bring stability to one of New England's agricultural industries.

The project was initially proposed by the Army Corps in 1980. There was considerable interest in carrying out the project, however the Corps did not have authorization for conducting such a demonstration project.

At my direction the Maine Department of Agriculture has aggressively sought funds to implement the project. Our efforts have included:

-- Site visits and interviews in Northern Maine by State Department of Agriculture officials and the development of conservation plans and irrigation system designs for demonstration farms by the SCS.

-- Formation and active involvement of a technical advisory group and a citizen's advisory group to guide the program's implementation.

-- The solicitation of financial support and equipment donations.

-- Incorporation of the program into the Maine Potato Industry Long Range Plan, 1982-86.

We continued our concerted efforts on behalf of this project until April 1982 when it became apparent that adequate project funds were not available prior to the '82 planting season.

We have undertaken several other programs that can work in tandem with this project to recapture Maine's share in the potato marketplace.

We have:

-- Implemented a state loan program supported by Maine voters with a $5 million bond in 1982 to develop and upgrade storage and central packing facilities to improve potato quality.

-- Approved, in 1983, $40,000 annual appropriation and significantly more stringent regulations supporting the improvements to seed potato production outlined in the industry long range plan.

-- Initiated a quality assurance and inspection program supported by $280,000 in appropriation by the Maine Legislature in 1983.

Although the Cropland Irrigation and Conservation Program is an important part of upgrading the industry, and in spite of considerable support and offers of voluntary and in-kind contributions we could not adequately fund the project without federal participation.

Continued assistance from the Army Corps in planning, design and construction of this project is critical to its successful implementation. The Corps has been active in the Northern Maine Region, and there exists a good working relationship between the Corps and the farmers, State and Federal agencies who will be actively involved in the project. There is a longstanding federal interest in providing cropland irrigation, beginning with the 1902 Reclamation Act, but little of that interest has been demonstrated in the Northeast. The Army Corps' continued support of this project is consistent with this interest.

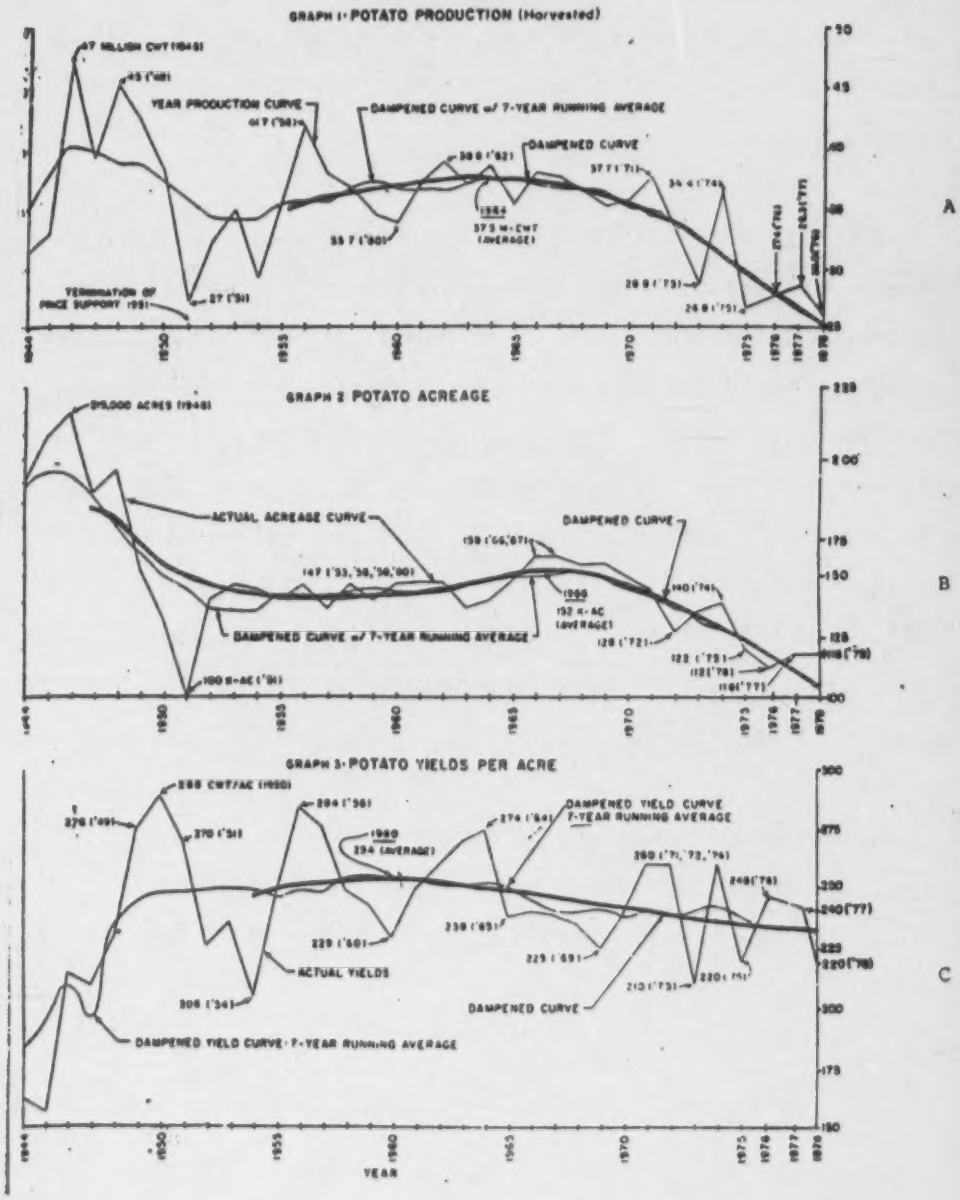
This project will bring many benefits to Maine. It will help strengthen an agricultural industry of national significance, and I strongly urge the committee's support of this program.

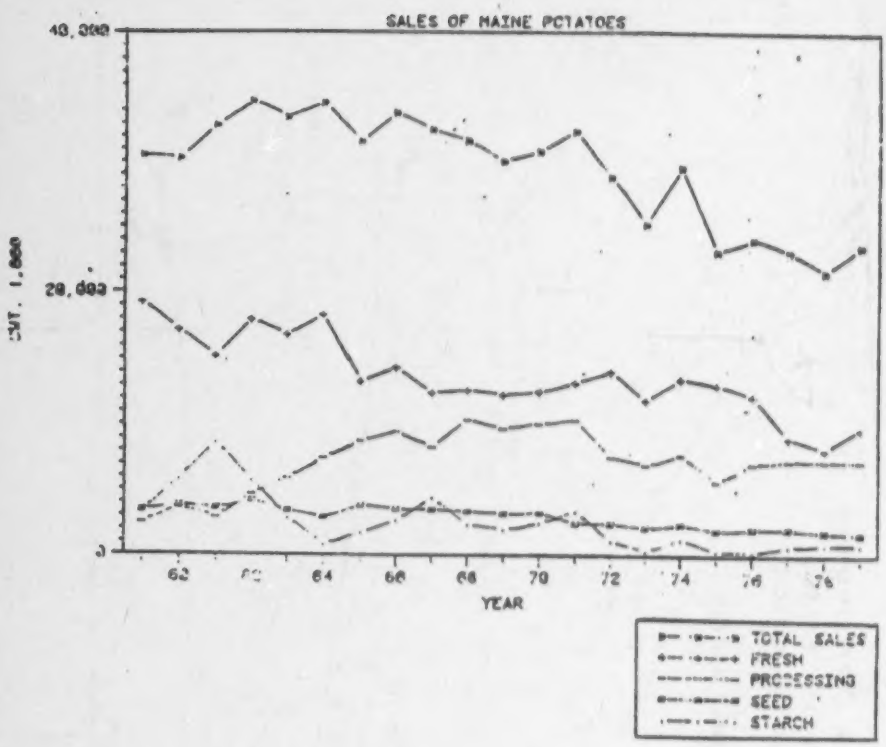
(E/8RURES)

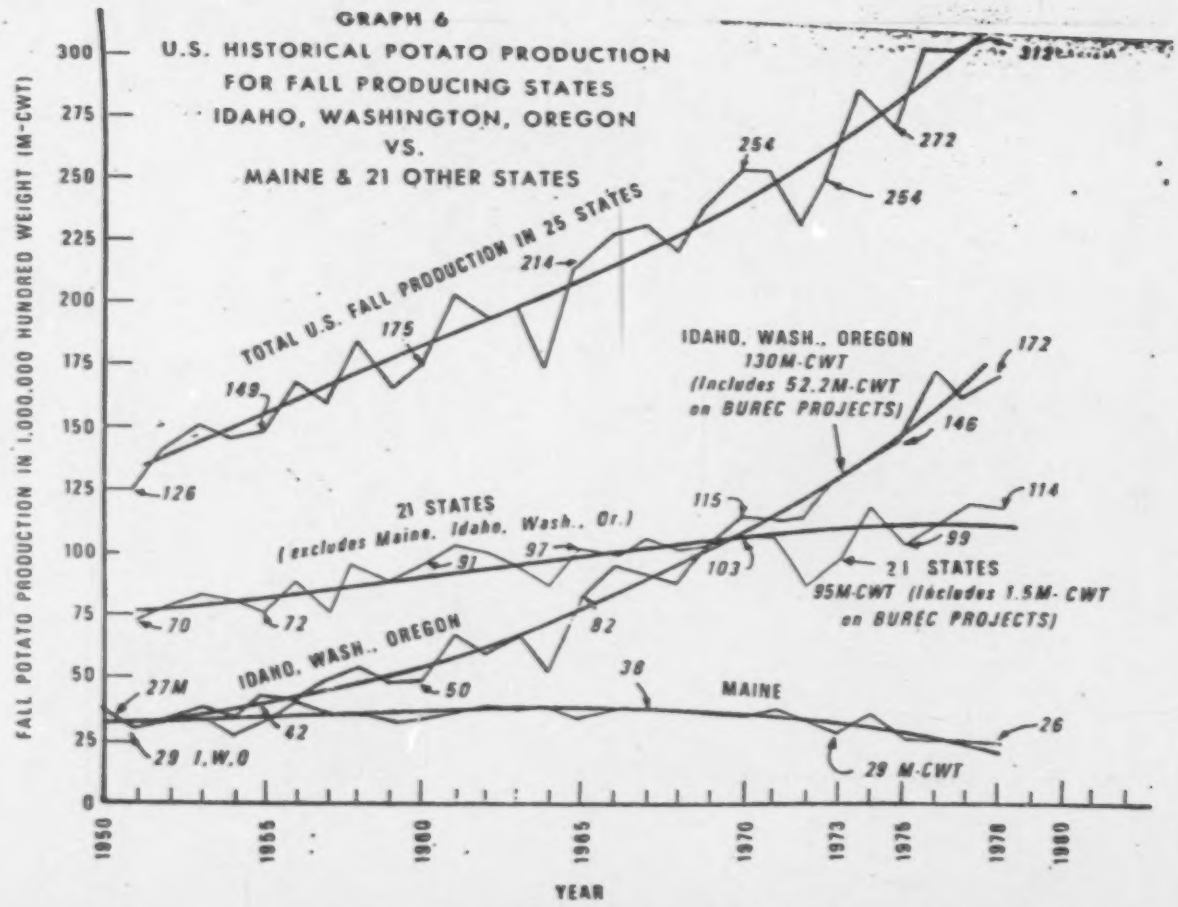
24-222 O - 83 - 5

Attachment

ST. JOHN RIVER STUDY: HISTORICAL POTATO STATISTICS, STATE OF MAINE
(LARGELY REPRESENTING AROOSTOOK COUNTY)




SALES OF MAINE POTATOES
40,000
20,000
0
62
64
66
68
70
72
74
76
78
YEAR
TOTAL SALES
FRESH
PROCESSING
SEED
STARCH


GRAPH 6
U.S. HISTORICAL POTATO PRODUCTION
FOR FALL PRODUCING STATES
IDAHO, WASHINGTON, OREGON
VS.
MAINE & 21 OTHER STATES
FALL POTATO PRODUCTION IN 1,000,000 HUNDRED WEIGHT (M-CWT)
YEAR
TOTAL U.S. FALL PRODUCTION IN 25 STATES
IDAHO, WASH., OREGON
130M-CWT
(Includes 52.2M-CWT
on BUREC PROJECTS)
21 STATES
(excludes Maine, Idaho, Wash., Or.)
21 STATES
95M-CWT (Includes 1.5M-CWT
on BUREC PROJECTS)
IDAHO, WASH., OREGON
MAINE
29 M-CWT
29 I.W.O
27M
126
149
175
214
254
272
254
312
70
72
91
97
115
103
172
146
114
99
82
50
38
42
26
300
275
250
225
200
175
150
125
100
75
50
25
0
1950
1955
1960
1965
1970
1973
1975
1978
1980

A SUBMISSION ON FUNDY TIDAL POWER

By

TIDAL POWER CORPORATION

Halifax, Nova Scotia

Background.

The tides in the upper reaches of the Bay of Fundy are among the highest in the world and there are feasible sites for the creation of large segregated basins through construction of dams. For these reasons, the Bay of Fundy is generally regarded as a leading candidate for tidal power development. Nevertheless, since the idea of tidal electric generation was first proposed in 1910, Fundy has remained the focus of unrealized hopes and the occasional scene of outright failure, while in the last 20 years tidal plants have been built in France, Russia and China.

In retrospect, it is easy to discern reasons for this lack of success. While tidal power was a common source of energy for many centuries, the Industrial Revolution ushered in a period of declining energy prices. By 1970, in real terms, energy costs had fallen to about 1/20 of their former value. Tidal power could not compete in terms of either price or convenience, and by the 20th century it had fallen into disuse. In effect, the economic dice were loaded against early attempts to harness the Fundy tides. Moreover, such early attempts suffered from insufficient understanding of the tidal resource and from other technological limitations.

In the last decade or so, economic and technical events have taken a turn more favourable to tidal power. In the early 1970's, OPEC pricing policies cast energy economics into a state of flux which has not yet stabilized. The changes have tended to improve the competitive position of tidal power. Studies of the Canadian section of the Bay of Fundy in 1966-69, 1976-77 and 1981-82 have increased our understanding of the tidal resource and have led to significant improvements in design and construction techniques.

The Present Position.

As a result of these studies, the economic potential for energy developments in the upper Bay of Fundy is fairly well defined. In summary:

(1) Sites can now be developed with a positive ratio of benefit to cost in Minas Basin and Cumberland Basin. It is possible that the ultimate development of the resource might also involve Shepody Bay.

(2) Annual energy outputs would range between 11,000 and 14,000 GWh per year for feasible sites in Minas Basin, which would yield the lowest at-site energy costs. Development of Cumberland Basin would yield approximately 3,400 GWh per year and Shepody Bay approximately 5,000 GWh per year. Thus the economically developable potential of the source is now considered to be ultimately about 20,000 GWh per year. Sites for Cumberland Basin (A8) and Minas Basin (B9) are shown in Figure 1. Characteristics of typical designs are presented in Table 1.

(3) The simplest forms of tidal plants are now understood to be the most economic. They do not yield continuous output and thus do not have any firm electrical capacity. The output would be in pulses of energy with a duration of about six hours per tide. While more complicated forms of tidal plant can produce continuous output with firm capacity, they are not under present conditions economic.

(4) Investigations both in Canada and Britain have indicated that tidal power from the simpler schemes is absorbable by utility systems without difficulty so long as tidal inputs do not exceed about 7% of total system energy inputs.

(5) The demand for electricity in the Maritimes is quite small and utility systems in those provinces could only absorb about 40% of the Cumberland Basin output or about 10% of the Minas Basin output. Therefore economic development of the upper Fundy sites would depend inevitably on the existence of export markets.

(6) Studies conducted by Tidal Power Corporation in 1981-82 with the co-operation of the New York Power Pool and the New England Power Pool indicate that there will probably be in the period 1995-2015 a large dependence on

hydrocarbon fuels in both New York and New England. The projections are shown in Tables 2 and 3.

(7) The same studies indicate that utility systems in the Maritimes, New York and New England are likely to have a surplus of generating capacity at least throughout the balance of the present century and that additional capacity will not be of any considerable value during that period. As a source of displacement energy, tidal power from Minas Basin or Cumberland Basin would be competitive in cost with nuclear power, would enjoy some cost advantage over coal and a large cost advantage over oil.

(8) The cost of tidal power is essentially non-inflating subsequent to the construction period. It is pollution-free. On the other hand, construction and operation of tidal plants would have environmental impacts, particularly on the aquatic environment.

Prerequisites for a Commitment Decision.

At this time, no project exists for the large-scale development of the upper Fundy tidal resource. Only feasibility studies have been conducted to date. They affirm that tidal power is economic and that a tidal power plant could be constructed in a certain way at a certain cost. This does not preclude the possibility that better designs at lower cost may be obtainable, nor do past studies supply any of the other information needed in order to make a commitment decision. It might cost as much as $100 million to obtain the required information. Obviously, before such an amount could be spent, there would have to be some assurance that the money was not being lavished on a non-starter.

Based on these considerations, the requirements leading to a commitment decision may be summarized as follows:

1. Prerequisites.

   1.1 Availability of export permits.

   1.2 Availability of markets.

   1.3 Availability of project financing.

2. If some degree of assurance were obtained on the above prerequisites, the way would be open for a pre-commitment program covering:

   2.1 Definitive design.

   2.2 Environmental assessment.

   2.3 Availability of transmission rights-of-way and/or conditional wheeling agreements.

   2.4 Conditional financing agreements.

   2.5 Conditional sales contracts.

On completion of the pre-commitment program, the necessary information would be at hand and a decision to commit or not to commit could be made.

The Nature of a Commitment Decision.

Such a decision could not be made in isolation by a proponent. The criteria used by Canada's National Energy Board in connection with the granting of export permits include, among other things, the requirement that the intended export will be beneficial and politically acceptable both to the exporting and the importing jurisdictions. Marketing and transmission requirements would hinge on the attitudes of utilities, regulatory bodies and state governments. It is immediately obvious from the foregoing that although the formal decision to commit might be made by a proponent, it could be vetoed in advance by many jurisdictions and agencies. In effect, commitment could only result from a large number of favourable decisions, while a decision not to commit would be the consequence of any single negative decision by any of the jurisdictions necessarily involved.

Tidal Power and the Environment.

Based upon present knowledge, the important potential impacts of Fundy tidal power development on the environment include imposition of higher mortality upon the American shad, and alteration of tidal ranges throughout the Bay of Fundy/ Gulf of Maine system. With the alteration of tidal ranges there would be associated changes in tidal currents and temperatures. There is a possibility, as yet not quantified, that such changes would affect the fishery, both in relation to food supply and in the distribution of fish larvae. Changes in circulation would be of minor physical magnitude but might have somewhat larger effects on fish stocks. Whether such changes would be beneficial or adverse is not known.

Many other potential impacts have been identified, but they are either likely to be minor, or are restricted to the locale of the site and thus not of concern to the United States.

Changes in the tidal regime have been quantified for certain cases through work done by Dr. D. A. Greenberg for the Tidal Power Review Board in the mid-1970's. They include in general a decrease in tidal range at the plant site and an increase in tidal range from some point in the upper Bay extending throughout the balance of the system. The extent of the change increases with the size of tidal development.

It is often possible to mitigate environmental impacts through modifications of project design. This is true in the case of Fundy tidal power for some impacts. It is the opinion of Tidal Power Corporation that ways must, and can, be found to reduce to acceptable levels the mortality imposed upon shad. However, it appears that the ability to reduce changes in the tidal range through appropriate design will be at least minimal, and probably non-existent.

Under circumstances where an impact is unavoidable and the damages are consequential, the alternative to abandoning the project is to provide compensation. In the opinion of Tidal Power Corporation, this is the correct approach in the case of damages arising from alteration of the tidal regime. The costs would add to the price of energy and be paid eventually by the users thereof.

At present, the environmental impacts of a large Fundy tidal power development are not sufficiently well quantified to support any value judgments. When it becomes appropriate to make such judgments, the requirement will be to weigh the remaining uncompensated adverse impacts of the project against the environmental and economic benefits. The environmental benefits would include the reduction of acid emissions, radioactive and other atmospheric pollutants associated with the displacement of energy from hydrocarbon fuels.

It is the submission of Tidal Power Corporation to this honourable committee that more information must be obtained before any logical judgment can be made, and that any premature attempt, leading to the polarization of opinion, is not in the best interests of any of the potentially-affected parties.

Environmental Regulation.

One unusual but by no means unique aspect of a Fundy tidal power development is that the environmental consequences would affect two countries.

Tidal Power Corporation has had limited experience in the construction of a project involving two separate areas of environmental jurisdiction. This experience has been gained in the construction of the Annapolis tidal generating station, in which federal and provincial jurisdictions are involved. In that case, a single intergovernmental body was formed to represent and reconcile the environmental interests of all the various agencies concerned. That approach has worked well. Where two countries are involved, it is recognized that it might be more difficult to employ a similar unified approach. Nevertheless, it is submitted that the advantages in terms of clarifying the objectives and establishing effective environmental control, without imposing undue delays or inefficiencies in project execution, are such as to justify serious consideration of the same approach in the case of a large Fundy project.

It is beyond the competence of Tidal Power Corporation to suggest the actual means by which a unified approach to environmental control and regulation could be established, but the Corporation suggests that this is one aspect deserving of early political consideration and discussion between the governments concerned.

Table 1

CHARACTERISTICS AND COSTS OF TIDAL POWER SCHEMES

		SITE 89			SITE AS
		1977 Construction Method	1981 New Method	1981 New Method	
1.	Total number of powerhouse units	106	106	128	37
2a	Number of Sluices (Shallow)	60	6	70	—
2b	Number of Deep Sluices	—	44	22	—
3.	Number of Spare Units	6	6	8	2
4.	Rated unit output MW	38	38	38	31
5.	Installed Capacity MW	4028	4028	4864	1147
6.	Net Plant Capacity MW	3800	3800	4560	1085
7.	Net annual energy GWh	11766	11766	14004	3183
8.	Capacity Factor (%)	35.4	35.4	35.1	33.5
9.	Cost Estimate ($x10^6)				
	(a) Total Direct Cost	3432	3524	4011	1153.2
	(b) Indirect and Interest plus contingency	2441	2493	3019	726.1
	(c) Total Capital Cost	5873	6017	7030	1879.3
10.	Annual Charge (9c) x .05531	324.8	332.8	388.8	103.9
11.	Cost of Energy mills/KWh	27.6	28.3	27.8	32.6

Note: The unit cost for the two "new 1981" schemes are not adjusted for the benefits due to energy and revenues during construction.

Table 2

NEW YORK
ENERGY PRODUCTION MIX WITHOUT TIDAL

Year	Hydro	Nuclear	S. Waste	Coal	Import	Oil	G.T.	Total GWh
1995	28288	32125	1758	60719	15978	11072	0	149940
2000	28288	32125	1758	60615	17784	20849	357	161776
2005	28288	32125	1758	93260	11358	7468	5	174262
2010	28288	32125	1758	117921	5570	1834	0	187696
2015	28288	32125	1758	135557	3611	862	0	202201

NEW ENGLAND
ENERGY PRODUCTION MIX WITHOUT TIDAL

Table 3

Year	Hydro	Nuclear	Coal	Oil	G.T.	Total GWh
1995	5853	56240	34559	30470	1116	128238
2000	5853	68128	43435	26307	1046	144769
2005	5853	93465	42308	21927	871	164424
2010	5853	118834	45149	16807	814	187457
2015	5853	142500	52933	10895	731	212912

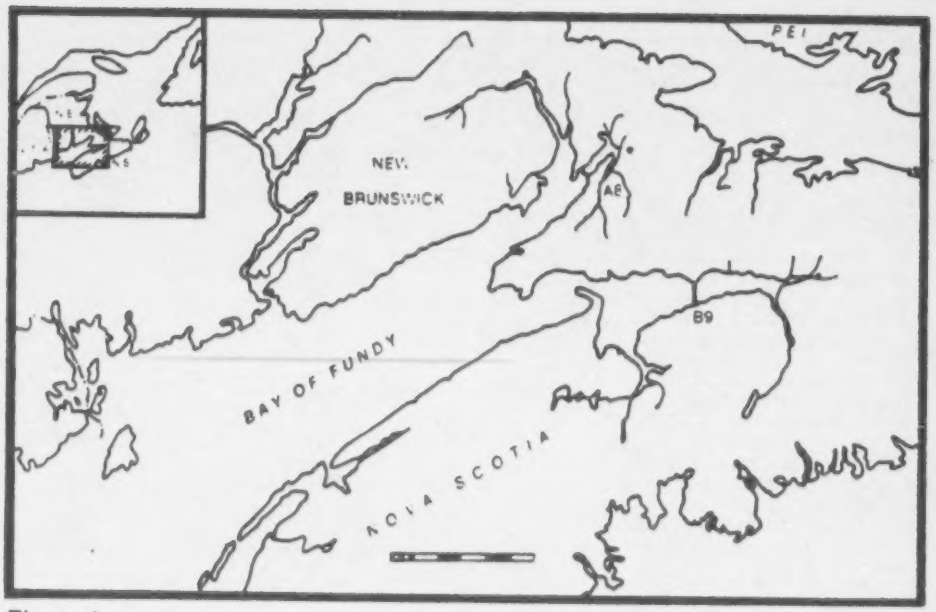


Figure 1

TIDAL POWER CORPORATION

POST-HEARING SUBMISSION

TO THE SENATE COMMITTEE

ON ENVIRONMENT AND PUBLIC WORKS

1. Scope.

This submission is intended to summarize testimony of G. C. Baker, P. Eng., before the Committee at Augusta, Maine, July 25, 1983 and to respond to the request of Senator George J. Mitchell for more detailed discussion of two matters included in the said testimony.

2. The Upper Fundy Tidal Resource.

The tides of the upper Bay of Fundy are potentially capable of providing some 20,000 GWh of electric energy per year, only a small part of which would be absorbable in the Maritime Provinces of Canada within the next three decades. The balance would be available to the New York - New England area for displacement of hydrocarbon fuels. Development appears to offer net economic benefits for all concerned.

3. Development Requirements.

Before development could be undertaken, the following would be required:

3.1 Reasonable assurance of the availability of markets, export permits and financing.

3.2 Pre-commitment work, including final choice of site, design and environmental assessment.

3.3 A decision to commit to construction.

4. Nature of a Commitment Decision.

A favourable commitment decision could only be made by a proponent if vetoes were not exercised by any of the jurisdictions necessarily affected, including but not necessarily limited to Canada, New Brunswick, Nova Scotia, the U. S. A.,

Maine, New Hampshire and Massachusetts. Insofar as United States jurisdictions are concerned, the vetoes would exist on a de facto basis by reason of:

4.1 The criteria for issue of Canadian export permits.

4.2 The ability to deny transmission facilities.

4.3 The ability to withhold regulatory approval of purchase contracts.

In addition, from the proponent's point of view, certain environmental disbenefits would have to be internalized and included in project costs, for reasons discussed in 6 below.

5. Environmental Effects on the United States.

It is not possible to separate the environmental effects explicitly on a national basis, since many of them would be common to both countries. There would be benefits from the displacement of oil and coal and the consequent reduction in atmospheric pollution (acid-forming oxides and radionuclides).

Unless mitigated by design, there would be extra mortality for some species of fish and there would be damage (as well as some benefits) from modification of the tidal regime. Such effects would be quantified by the environmental assessment listed in 3.2 above.

6. Compensation for Certain Damages.

Changes in the tidal regime may not be avoidable through plant design. In that case, compensation would have to be offered. To the best of the Corporation's present information, cost of damage compensation would be small in proportion to the capital costs of a large Fundy project. The United States would not have to depend on the uncertainties of international law for compensation of damages: any award by a U. S. court could be enforced simply by impounding the project's U. S. accounts receivable.

The following ideas relate to compensation:

6.1 Formal arrangements should be in place prior to commitment.

6.2 To avoid overloading the courts and to give every citizen cheap access to justice, an agency should be designated to assess and arbitrate claims, with right of appeal to the courts.

6.3 The classes of damage to be compensated should be agreed in advance. They should include all private claims, but not necessarily claims by state or federal governments, since those governments would also be receiving any environmental benefits emanating from the development.

6.4 It might be necessary from the proponent's viewpoint to set a top limit on the total of compensation to be paid by the project; otherwise, it might be impossible to secure financing. Such a limit, based on the environmental assessment plus a margin for error, would have to be agreed between the national governments.

6.5 It would not be necessary to require the proponent to put up funds in advance for payment of claims, since the project's current U. S. earnings would provide the necessary security, either by assignment or impoundment.

7. Protection of United States Environmental Interests.

From the foregoing, it is obvious that the United States does not lack the means to protect its environmental interests on a unilateral basis. However, a joint approach to the problems of environmental regulation and control would offer important advantages, including the establishment and clarification of environmental objectives and the avoidance of undue delays and inefficiencies in project execution.

The vehicle of joint action might be the International Joint Commission or an ad hoc group. Such groups were used to negotiate the Columbia River Treaty and to draft an agreement respecting the proposed Dickey-Lincoln School project on the upper St. John River.

Each alternative has some advantages. Utilizing the International Joint Commission would probably be the easiest and quickest course. On the other hand, formation of an ad hoc group would provide better scope for representation of the particular interests and the inclusion of the particular abilities most appropriate to cope with the environmental regulation of a tidal power project. A single-purpose agency would not find itself faced with conflicting claims upon its time.

8. Preparatory Environmental Work.

At present, the prerequisites listed in 3.1 above have not been satisfied and there is no declared proponent for a tidal power project. The identity of a possible proponent is not known. It would probably be a group, which might include Tidal Power Corporation. Under these circumstances, only very limited activities of organizational or environmental nature looking forward to a tidal power development would be justified. In Canada, for the past five years, there has been a broad attempt to close gaps in the fundamental understanding of the ecological systems extant in the Bay of Fundy. A good deal of progress has been made, but some gaps remain. This work has been co-ordinated by the Fundy Studies Committee, of which the Chairman is Dr. G. R. Daborn, Acadia University, Wolfville, Nova Scotia. It is suggested that any environmental work on Fundy undertaken by U. S. agencies should at present be limited to fundamental research and should be co-ordinated with Canadian efforts.

9. Opinion Should Not be Polarized Now.

It is a plain fact that any tidal power project of the size contemplated would on balance have to be beneficial to all concerned, and so perceived; otherwise, it could not be built. This fact is not generally recognized.

At present, the valid concerns of environmental professionals are being emphasized by sensation-seeking media, while the environmental benefits go unreported. There is some danger that public opinion will be adversely affected to the extent that potentially beneficial tidal developments will be precluded.

There is a need to reserve judgment until the economic and environmental facts are fully established.

July 18, 1983

The Effects of Tidal Power Development on the Physical Oceanography of the Bay of Fundy and Gulf of Maine

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Abstract

Predicted changes in physical oceanography due to the installation of tidal power barriers in the upper Bay of Fundy are reviewed. Away from the barrier site, the changes induced are small compared to the natural variation in the system, but still of potential significance in many areas. Changes in the vicinity of the barrier and in the headpond would be more dramatic and depend on the type and level of installation.

Introduction

Although tidal power has been studied for some time, with schemes considered in Passamaquoddy (see for example IPEB 1961), and in the Upper Bay of Fundy (ATPPB 1969) it was not until the study of the BFTBR (1977) that wider issues of the environmental effects of the schemes in the upper Bay were addressed (Daborn 1977). It was also realised around this time that the changes in tidal response would be more far reaching than previously thought (Heaps and Greenberg 1974).

In this paper possible changes in the physical oceanography of the Bay of Fundy due to tidal barriers are described and compared the natural variation in the system. The changes in tidal sea levels, as found in

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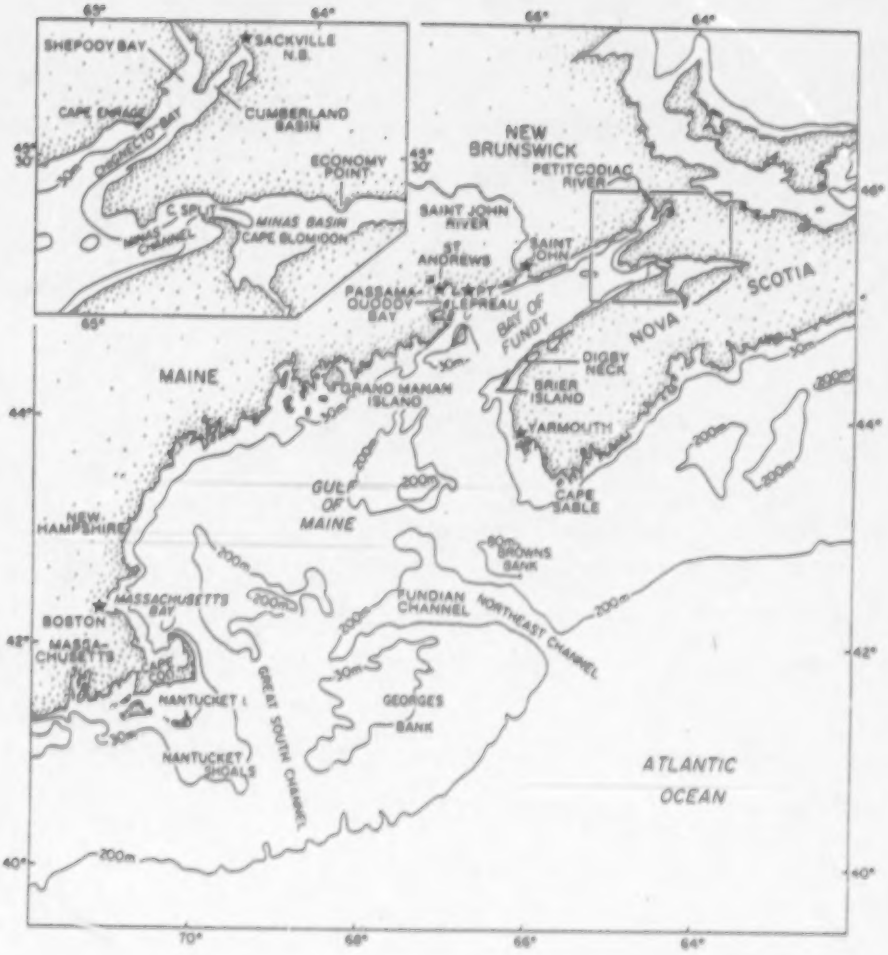

Fig. 1. The Bay of Fundy and Gulf of Maine.

numerical model studies (Greenberg 1979), are presented and some implications of these changes are discussed.

Tidal Elevation

Changes in the tidal response of sea level in the Bay of Fundy and Gulf of Maine due to tidal power development have been calculated using a numerical model (Greenberg 1979). These are accounted for in terms of the free period and energy characteristics of the system. The barrier locations most favored are in upper Chignecto Bay across Shepody Bay, across Cumberland Basin and in Minas Basin at Economy Pt. (Figure 1).

Barriers across the mouths of Shepody Bay and Cumberland Basin would give rise to very similar changes in tidal regime. The M_2 tidal amplitude of the sea level elevation (Figure 2) decreases at the barrier and throughout the upper Bay of Fundy. The magnitude of this change diminishes from the head of the Bay changing to an increase in tidal amplitude in the lower Bay and throughout the Gulf of Maine. There seems to be little change away from the Gulf along the continental shelf.

These widespread changes are caused by the shifting of the free periods of the Bay of Fundy and of the combined Fundy-Maine systems. Resonant amplification occurs when a system is forced near its preferred period of oscillation. The Bay of Fundy has a natural period of oscillation of about 9 hrs. (Rao 1968). A barrier which shortens the Bay, decreases this period, moving it further away from the forcing tidal period of 12.42 hours, which decreases the amplification from the mouth to the head of the Bay. The period of the Bay and Gulf combined is about 13 hours (Garrett 1972, 1974). Shortening this period brings it closer to the tidal forcing period, thus increasing the resonant amplification. In the

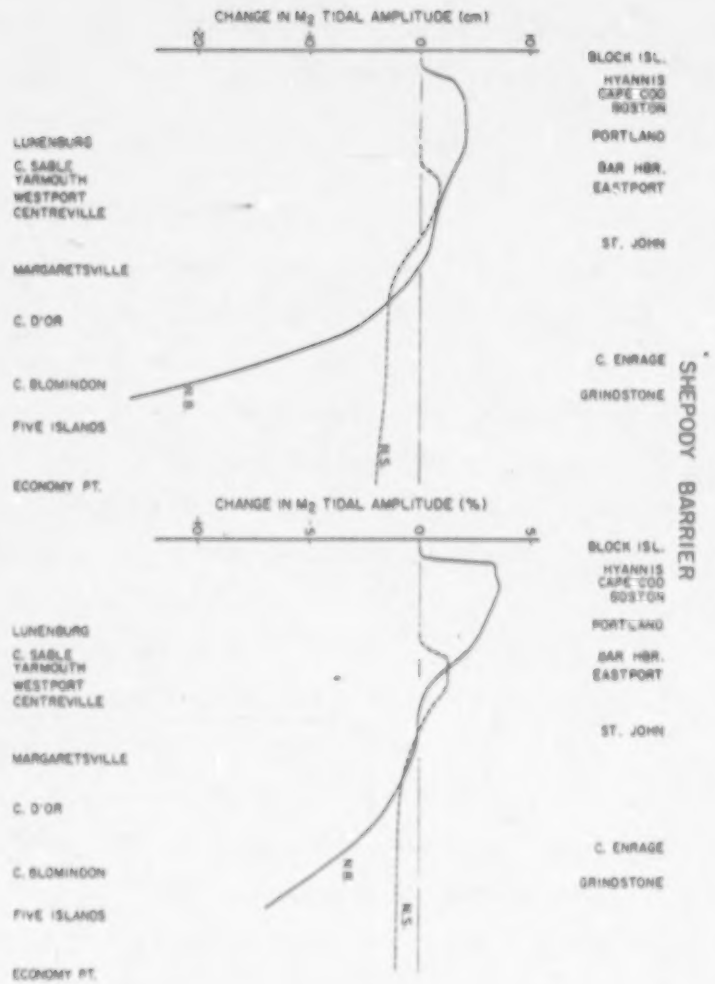

Fig. 2. Absolute and percentage change in tidal amplitude along the coast, due to a barrier installed at the mouth of Shepody Bay.

Bay of Fundy these two effects compete causing the tidal sea level decrease which dominates at the head of the Bay and the increase which dominates at the mouth.

A barrier in the Minas Basin at Economy Point leads to larger increases in tidal amplitude throughout the Bay and Gulf (Figure 3) except for the area very close to the barrier. The difference in the regimes resulting from these two barrier locations is the result of the reduced transport at the Economy Point barrier site being felt downstream near Cape Split releasing energy that is dissipated by friction in the natural system. Increased capacity would necessitate more or larger turbines and greater flow. Consequently, an increase in capacity of the Economy Point barrier decreases further the tide at the barrier because increased flow leads to more energy dissipated by Cape Split. Changes in the capacity of Shepody and Cumberland barriers had little effect at the barriers and in all cases capacity changes had little effect downstream. Similarly, differences in types of generation (see "Headpond Tidal Affects" below) would have comparable effects away from the barrier site.

Confidence in Calculations

Error limits on the changes given in Figures 2 and 3 are difficult, if not impossible to derive. Confidence in the predictions is gained through an understanding of the physics involved, by noting the consistency of the nature of the change with other researchers, and by obtaining similar results with the progressive refining of the model. Garrett and Greenberg (1977) and Garrett and Toulaney (1979) showed that any errors due to open boundary effects would be minimal (of order 1%) for the barrier cases now under consideration. Garrett (1974) showed in his normal mode

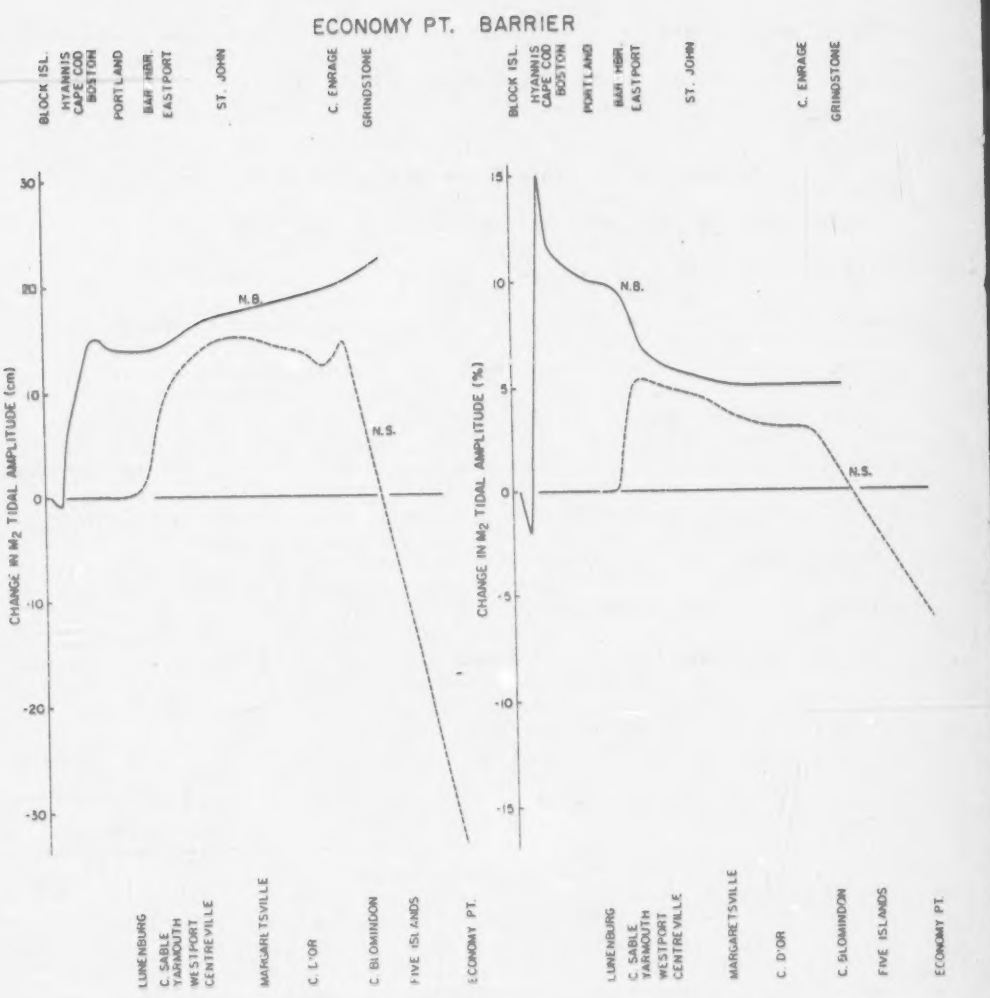

Fig. 3. Absolute and percentage change in tidal amplitude along the coast, due to a barrier installed across the Minas Basin at Economy Point.

study that the shortening of the Bay of Fundy changed the shape of the Fundy-Maine oscillation. Although his grid was coarse and the equations were simplified, he predicted a reduction in amplification at the head of the Bay and an increase at the mouth and in the Gulf as is suggested in Greenberg (1979) on which this paper is based.

More recently, Duff (1981) has obtained similar patterns and percentage changes to those of Greenberg (1979) using a numerical model that telescoped to include much of the North Atlantic. This also showed minimal change along the edge of the continental shelf where Greenberg (1979) specified tidal elevations unaltered when barriers were simulated. The magnitude of the changes predicted by Duff did differ, but it is thought that this was due to poor calibration of the model, it being up to 30 cm out in amplitude and up to one hour out in phase of the tide. Duff did get results different from his full model when using a cut-down continental shelf model, using inappropriate open boundary conditions in which currents were specified not to change when barriers were simulated.

The Bay of Fundy-Gulf of Maine model referred to here, has gone through a considerable development from its first trials in Greenberg (1975) (Figure 4) to its present form (Greenberg 1979, Figure 5). This has lead to some revision in the magnitudes of the predicted changes but little difference in the pattern of the change. Among the steps in this evolution, some of which are obvious from the diagrams, are the following:

1. The inclusion of the shallow area at the head of Cobequid Bay.
2. The inclusion of advective terms in formulations of the equations in the Minas Basin and Minas Channel
3. The creation of a new, finer grid for the Minas Basin and Minas Channel area.

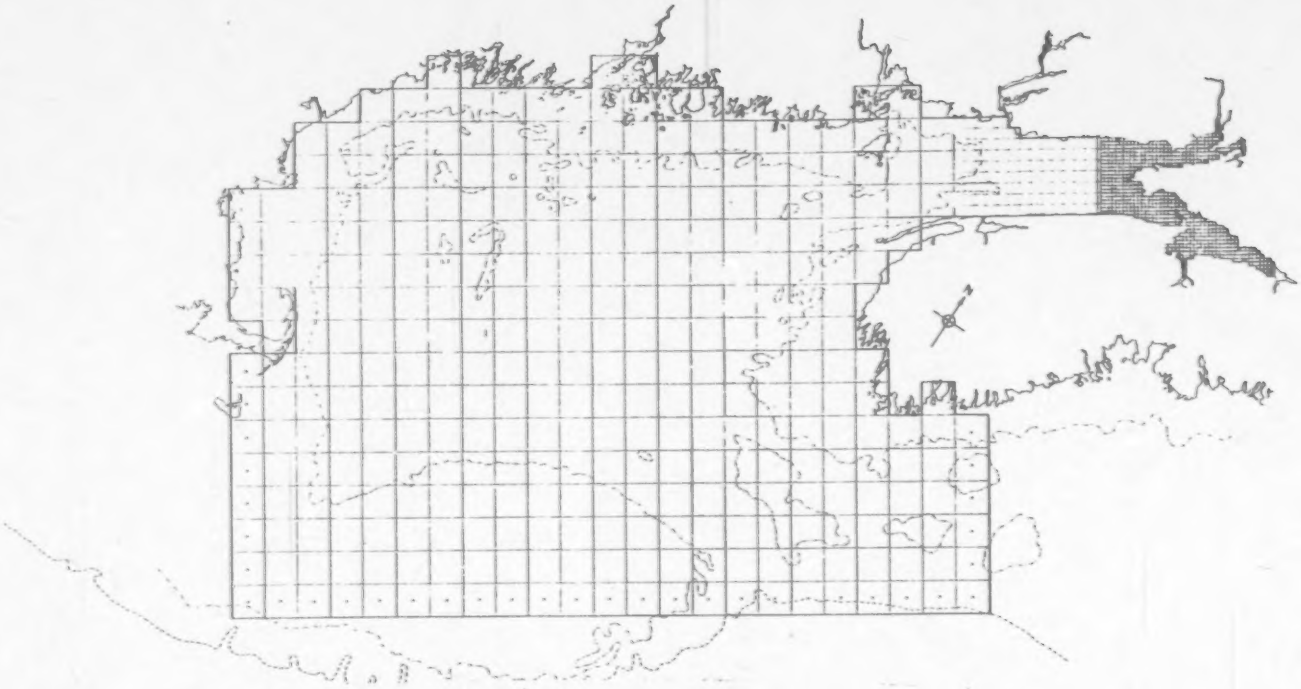

Fig. 4. The grid outline of the earliest version of the Bay of Fundy - Gulf of Maine numerical model (from Greenberg 1975).

4. Recalibrations carried out along with the above three changes resulted in the lowering of the friction coefficient from an unusually high 6.4 x 10^{-3} to within a normal range at
2.1 x 10^{-3}.

5. The medium size grid was extended out to the mouth of the Bay of Fundy.

6. The coarse grid was extended out to the edge of the continental shelf and to the northeast and southwest along the shelf.

7. Variations due to map projection and the changes with lattitude of the Corioles parameter were allowed for in the coarse grid.

8. An extensive data collection program was undertaken which permitted a precise specification of the open boundary tides and very accurate calibration of the model.

Calculations using the above mentioned models all gave similar qualitative results, but quantitatively there was an increase in effect. The tide change at Boston, for example, increased progressively from a 6% rise to a 10% rise as the more accurate schemes were incorporated. The change in tide phase at Boston differed only from a 6 minute delay to a 4 minute delay in the later calculations.

A further test was carried out to see whether barrier effects would be poorly predicted because of the coarse resolution of the Gulf of Maine coastline. The depths around the coast of the Gulf were doubled, and simulations were run with and without barriers. The percentage change in tides due to barriers was found to be the same as predicted with realistic depths. It was reasoned that if such gross errors did not alter the predicted change, then more comprehensive modelling of the Gulf would give more detail, but not increase the accuracy of the prediction.

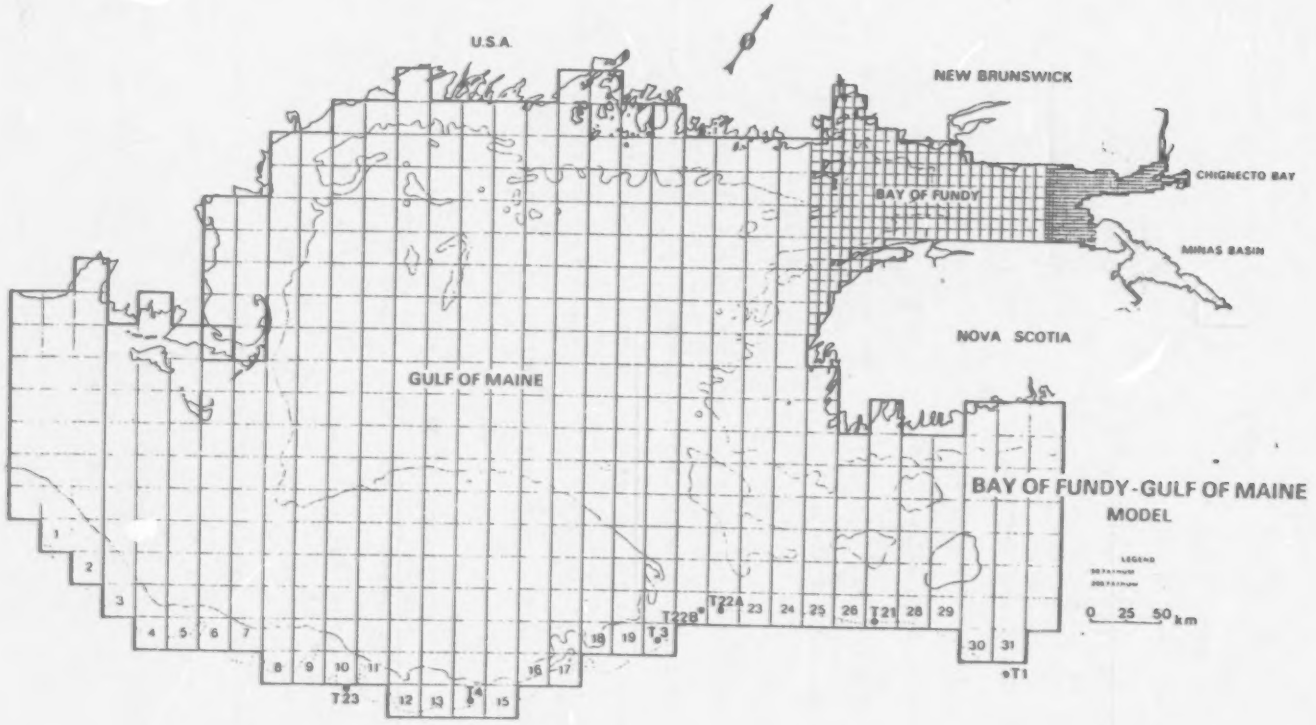

Fig. 5. The grid outline for the latest version of the Bay of Fundy - Gulf of Maine numerical model (from Greenberg 1979).

Barrier effects and natural variability

The changes in M_2 tide should be considered in conjunction with the natural variability of sea level in the system.

Computer runs have been made simulating the major tidal constituents for 30 days to examine the complete monthly variation in tides. The hourly output from the model was analyzed using a standard tidal analysis package and the simulated constituents were compared for cases with and without barriers. Times and heights of high and low water were also interpolated. The results (e.g. Table 1. Economy Pt. Barrier) indicate the largest change in amplitude for the M_2 constituent. Away from the head of the Bay, the other constitutents are changed principally in phase. Except in the immediate vicinity of the barrier, there were no changes in mean sea level. The average of the mean differences in high and low water are very close to the change in M_2 amplitude, although there are differences in the changes at high and low water. This could be real or due to inaccuracies in the interpolation scheme, particularly near the barrier, where the opening and closing of sluices and turbines could disproportionately influence results. This requires further investigation.

Changes in tidal sea level elevations of a few centimeters might tend to be camouflaged by surface waves, storm surges and even the natural tidal variation. It would be the extremes, spring and neap tides, that would be most noticeable (see Figure 6). In a period of neap tides, low areas that would normally not be exposed and higher areas that would normally not be covered for one or more tidal cycles, would be covered and exposed respectively every tide. During a period of spring tides, areas that would never be exposed or covered by the natural tides, would be included within the outer range of tidal variation.

TABLE 1. Difference between model run with an Economy Point barrier and without barriers, of high and low water heights and times, and of the major constituents simulated.

	At Barrier	Grindstone	St. John	Boston
HW Mean Difference	- 53.1 cm - 31.7 min	+ 31.4 - 6.2	+ 20.9 - 2.6	+ 12.0 + 0.9
Standard Deviation	6.8 cm - 2.7 min	4.7 2.8	1.8 2.3	0.6 1.4
LW Mean Difference	+ 25.8 cm - 29.3 min	- 20.0 - 8.8	- 19.7 - 6.5	- 15.8 + 7.2
Standard Deviation	9.5 cm - 3.0 min	3.3 1.6	2.6 2.0	1.2 3.4
O_1	12 cm 143°	12 143°	11 129°	10 142°
Difference	- 1 cm 7°	0 - 2°	0 - 1°	0 0°
K_1	15 cm 137°	15 129°	13 124°	12 136°
Difference	- 1 cm - 8°	0 0°	- 1 + 1°	0 0°
N_2	92 cm 336°	86 321°	58 311°	29 326°
Difference	- 1 cm - 15°	+ 3 - 2°	+ 2 - 1°	+ 1 + 3°
M_2	559 cm 1°	501 349°	322 340°	150 358°
Difference	- 29 cm - 16°	+ 25 - 3°	+ 19 - 2°	+ 13 + 3°
S_2	88 cm 46°	81 30°	51 18°	22 31°
Difference	- 1 cm - 17°	+ 4 0°	+ 2 + 1°	0 + 6°

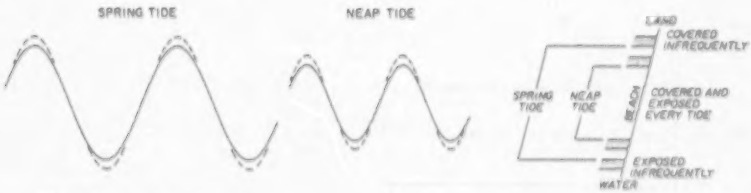

Fig. 6. The changes in spring and neap tide ranges and shoreline impact due to an increase in tidal amplitude. Changes are exaggerated for clarity.

There are many instances where increased tidal amplitudes could have an effect. Impacts which could be felt include:

1. Areas sensitive to present high water: those having low beach slope, already bothered by storm surges, salt marshes, or built up close to present high water would be most affected.

2. Shorelines sensitive to wave attack would find the waves consistently hitting higher and lower levels of the beach, but diffused over the wider tidal range.

3. Marginal ship passage would be more risky for the lower half of the tidal cycle but safer during the higher half.

4. The flood risk in the lower Saint John river valley may be more severe if higher high waters further retard high runoff in the spring.

Tidal Effects in the Headpond

The largest changes from the present regime, due to the installations of a tidal power plant, would be behind the barrier. The preferred type of installation known as ebb generation, consists of an enclosed reservoir or headpond, which is filled through sluices at high water and drained through turbines at low water generating electricity (Figure 7). Other generation modes have been considered, with two way generation being a possibility, but flood generation is uneconomic. The tidal sea level changes in the headpond would be reduced to one half to one third their present range under any mode. The mean level of the reservoir depends on the particular generation mode (Figure 8), being higher than normal for ebb generation, lower for flood generations and only slightly raised for two-way generation. The level of installed capacity also has an effect (Table 2). Greater sluice capacity tends to increase the mean headpond level, and

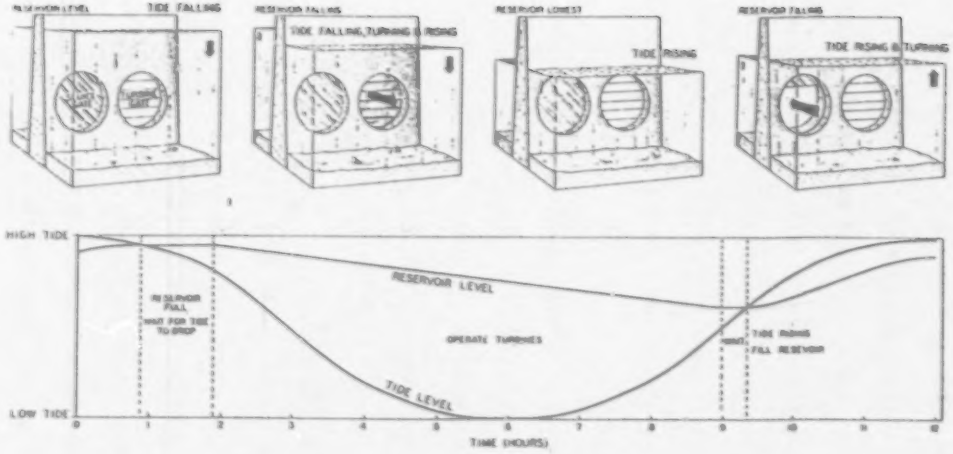

Fig. 7. The different stages of operation in an ebb generation power scheme relative to tide and reservoir levels.

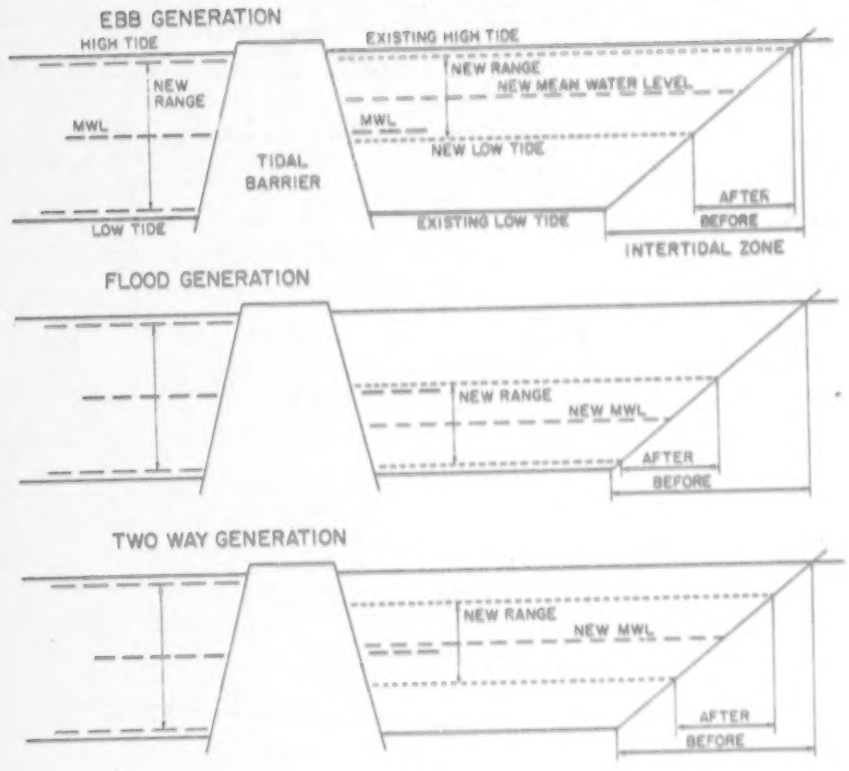

Fig. 8. Reservoir levels for different generation modes.

TABLE 2. Variations due to different installation levels. Experiments were done with an early version of the model, and barriers operating characteristics have evolved, so exact numbers would differ, but trends should be the same. Present thinking calls for even higher installation levels.

EXPERIMENT	1	2	3	4
M_2 Amp in Front (cm)	548	538	563	546
M_2 Amp Behind (cm)	167	227	94	171
Mean Level Difference Across Barrier (cm)	340	277	436	373
Generation Time (min.)	364	339	402	374
Sluice Time (min.)	222	249	183	210
Number of Turbines	70	105	35	70
Number of Sluices	70	70	70	100

higher turbine installation tends to increase headpond range. The mean level in ebb generation tends to mimic the variation in high water (Figure 9) due to the higher resistance to flow of turbines compared to sluices. This effect is similar to that of Reversing Falls on the water levels in the lower Saint John River. The mean level in flood generation would tend to follow the low water variation but would vary less in two way generation.

Two-way generation is the only mode where some power can be had on demand for short periods. To achieve this, the demand must be sufficiently forecast and it in such instances might be necessary to give up some energy to have the basin level optimized at the correct time. For maximum power production, a two way scheme would be generating in an ebb generation mode during priods of low tides and in both directions during medium and high tide periods. Both of these factors could lead to a more irregular variation in mean reservoir level and in the extent of the intertidal area.

From the above, we can see that changes in the headpond tidal regime will impact the area in two different ways, by changing the mean sea level and by changing the regularity and extent of the intertidal area. Factors that could depend on the mean water level include changes in the level of, and salt intrusion into, the watertable of the surrounding land, and the drainage of aboiteaux. Changes in intertidal area could lead to changes in erosion,sedimentation and biology.

Other Factors

Changes in tidal currents can be expected in similar magnitudes to changes in tidal elevations. A relationship has been found connecting the strength of the tidal current and the water depth to whether or not an area

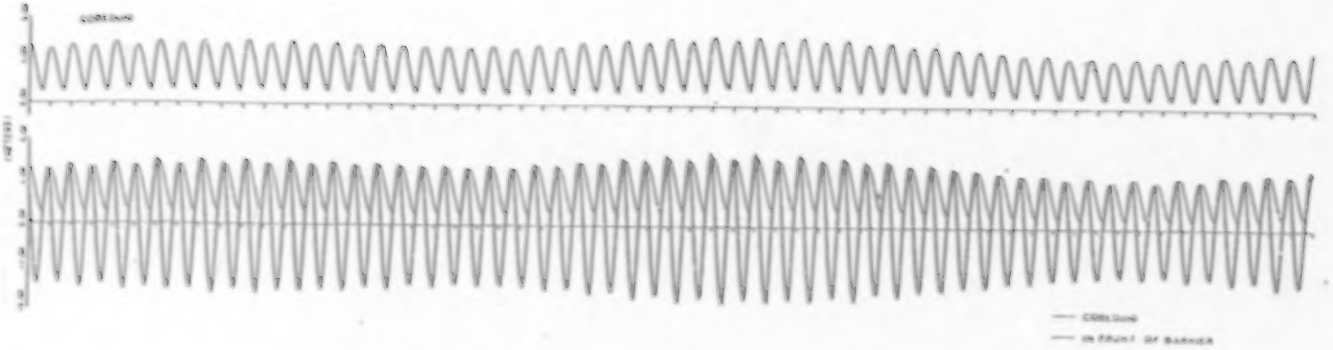

Fig. 9. Variations of tide and reservoir level at an ebb-generation tidal power barrier over a 30 day period.

is well mixed or stratified. In an analysis of tidal mixing, Garrett et al. (1978) found that the Great South Channel changed from being marginally outside the critical range for a tidally mixed area, to marginally within this range (Figure 10) when tidal power barriers were simulated. This could have implications for water mass exchange through the Channel. The study also indicated the headpond area would tend to stratify in the summer. Holloway's (1981) study suggested a significant decrease in salinity in the headpond which would tend to increase any tendency to stratification, but little effect on salinity was predicted for the area outside of the tidal reservoir.

The placement of a barrier could have a locally significant effect on waves. The long channel fetch would be reduced, decreasing the energy level of the waves downwind from the barrier. Reflections of waves at the barrier could cause a local increase in wave energy.

Several factors relating to a barrier's installation could affect ice conditions. These include: decreased breaking forces on the ice due to lower wave activity, lower salinities, tidal range and tidal currents, limited tidal excursion due to the barrier and possibly greater ice formation due to decreased mixing. These factors could induce the present large quantities of drifting ice to form a more solid ice cover. Whether this could lead to complete fast-ice cover in the headpond has not been determined. The subject of ice is more completely covered in Gordon and Desplanque (1981).

Concluding Remarks

The predicted changes in tidal elevations and tidal currents due to the proposed installation of a tidal power dam in the upper Bay of Fundy

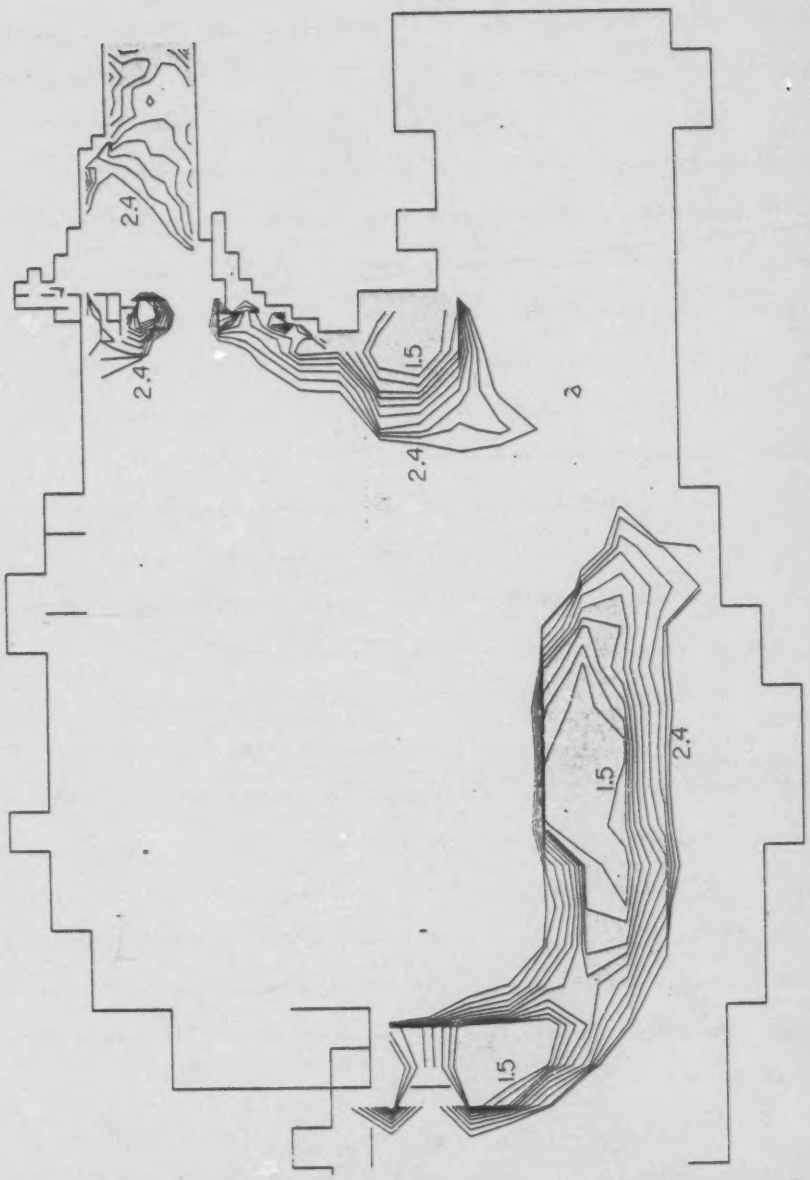

Fig. 10. The mixing parameter, Depth/Dissipation, in the Gulf of Maine when a barrier is simulated at Economy Point (from Garrett et al. 1978). The Great South Channel is included in the mixed region.

are now fairly well understood. Although, away from the barrier, the changes may seem small compared to the natural variation in the system, they still could be significant in many areas. Good quantitative analysis on how these changes could impact flooding, shipping, mixing etc. have not been made. Perhaps estimates should be made on a site specific basis. An attempt has been made here to give some qualitative ideas on impacts based on what is quantitatively understood.

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DEPARTMENT OF THE ARMY
COASTAL ENGINEERING RESEARCH CENTER
CORPS OF ENGINEERS, KINGMAN BUILDING
FORT BELVOIR, VIRGINIA 22060

REPLY TO
ATTENTION OF:

CERVY

1 July 1982

SUBJECT: Review of 1977 Thesis by D. A. Greenberg Entitled, "Mathematical Studies of Tidal Behavior in the Bay of Fundy"

Commander
US Army Corps of Engineers
ATTN: DAEN-RDC
Washington, D.C. 20314

1. This review was prepared at the request of Mr. J. Pfeiffer, DAEN-RDC, for the purpose of obtaining a Corps of Engineers Laboratory evaluation of the subject paper, to solicit recommendations for potential further study, and to assess available laboratory expertise and capability to execute additional investigations required to reliably quantify the oceanographic, coastal, water quality, and environmental impact of the proposed Bay of Fundy Tidal Power Station.

2. Review comments and proposed studies contained herein were coordinated (by telephone) with and represent a preliminary evaluation of personnel in CERC, WESEH, and WESEV.

3. Comments on the content and scope of the subject thesis follow:

a. Dr. Greenberg's thesis describes a vertically integrated numerical tidal model set up to test the effects of alternative tidal barriers installed in the upper reaches of the Bay of Fundy. This Bay feeds into the Gulf of Maine and out to the Northwest Atlantic Ocean. The barriers model the presence of a tidal power station which takes advantage of the extraordinary high tides in the Bay.

b. Previous modeling efforts have indicated that tidal barriers in the bay probably influence a large area including the Gulf of Maine. Consequently, the Gulf of Maine, continental shelf and Bay of Fundywere incorporated into the model as a combined system.

c. To make the model feasible in terms of computer time and memory, a method was developed to incorporate finite difference grids of differing sizes in different regions. This allowed fine resolution to be achieved in the area of primary interest, i.e., Bay of Fundy, and coarser resolution in the rest of the model domain (Gulf of Maine and continental shelf). Flooding and non-linear advection were accounted for in the model.

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d. The spatially varying amplitude and phase of the M2 tidal constituent were input along the seaward deep water boundary of the model. They were adjusted in the absence of barriers until approximate model calibration was achieved. The model was then run using the same adjusted M2 boundary tide with four different barrier schemes to simulate permeable and impermeable barriers, (i.e., different types of power generation stations).

4. Review comments are enumerated below:

a. The numerical model described in the thesis appears to be a good "first cut" at ascertaining the hydrodynamic effects of the tidal power barrier schemes. We have reservations about some of the model results and details. Some of these reservations follow in items b thru i of this paragraph.

b. The numerical model was calibrated but not verified. Additional tide measurements are necessary for a more complete model calibration and verification in order to have sufficient confidence in the model results to use them as a basis for the important decisions required concerning effects of this potential project.

c. The bed elevations used in each grid cell were not given. This made it impossible to determine how realistically the bathymetry was represented in parts of the model. In particular, it's not clear how well the bathymetry near the U.S. coastline was represented.

d. The rationale for the barrier-weir coefficients was incomplete. Even though the person (Wilson) who arrived at the coefficients was given, there was no explanation of how Wilson arrived at his values. All that was stated was that Greenberg got his values from Wilson through a "personal communication."

e. Gulf of Maine-Bay of Fundy response seems somewhat sensitive to location of the seaward boundary, depth distribution along this boundary, and, of course, to the M2 amplitude and phase distribution along the boundary. A more detailed sensitivity study is necessary to quantify how the boundary location and depth distribution, and the M2 amplitude and phase distribution affect tidal response of the system.

f. As noted by Dr. Greenberg and others, the Gulf-Bay combined system is nearly resonant with the M2 tide. It is well known that even small non-linear interactions can significantly alter the response of a system near resonance. It is probable that tidal constituents other than M2 will interact non-linearly with the M2 constituent. Results of Greenberg's thesis do not address this crucial question. A more complete and reliable representation of the tidal constituents (amplitude and phase of sufficient constituents to comprise at least 96% of the total tidal energy) on the seaward boundary is necessary to reliably quantify the actual response of this complex system to the real tidal input (rather than the response of the system to only the M2 constituent). The amplitude of the M2 constituent comprises only about 70% of the total tidal amplitude.

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g. Stratification effects (three-dimensional effects) including modification of the temperature, salinity, and other important physical, chemical and biological constituent distributions in the Gulf of Maine-Bay of Fundy were not studied. Potential modification of these oceanographic parameters must be quantified to ascertain the extent of environmental impacts of the marine fisheries and shellfish industries of the entire area.

h. Combined effects of winds and tides were not studied using the actual prototype bathymetry. Conceivably, a tide and strong northeaster, combined with a given barrier configuration, could "significantly" modify the hydrodynamics from what it would be in the absence of the barrier. This modification has the potential for even more serious impacts to water levels in United States waters along the entire New England coast.

i. Boston has the highest predicted percent change in tidal elevation due to barrier placement. This result is somewhat suspicious since Boston is the most distant city (within the study area) from the barrier. Such an anomalous water level behavior could conceivably be due to the near resonance of the Gulf of Maine-Bay of Fundy system. It also could be due to the lack of spatial resolution near Boston or to anomalous boundary effects of the numerical model. A study using a finer grid near Boston and a sensitivity study of model boundary effects are necessary to clarify whether the predicted changes are a result of insufficient spatial resolution, model boundary effects, or are "real".

5. Recommendations based on the content and evaluation of Greenberg's paper follow:

a. Greenberg's thesis clearly shows that the barriers studied have sufficient potential impact on water levels to be a serious cause of concern to the United States should the project be seriously considered.

b. The regional and national importance of the proposed tidal power station and its potential impact on the entire New England coastline make it absolutely essential to develop and expeditiously pursue a study plan which will quantify these potential oceanographic, coastal and environmental impacts.

c. The only rational method of quantifying these potential impacts with a reasonable probability of success is by numerical modeling the entire New England/Nova Scotia continental shelf and coastline. This numerical oceanographic model must be three dimensional over the entire study area, must allow for land flooding, and must be implicit in the computation of surface elevations (in order to be economically feasible). CERC (in concert with WESHH) has a numerical model developed and sufficiently well calibrated and verified to be confident of its applicability to this important problem. We recommend that the three dimensional model developed under work unit No. 31675 by Dr. Peter Sheng, Aeronautical Research Associates of Princeton (ARAP) be applied to this problem. This application will be a joint fully integrated undertaking by CERC, WESHH, WES Environmental Laboratory and ARAP. Additional field and office studies of chemical and biological oceanographic parameters also may be used.

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d. A prototype data acquisition effort is necessary to quantify the amplitude, phase, and volume transport of tidal constituents at the proposed numerical model boundaries. It also may be prudent to conduct a field study to quantify effects of the small pilot tidal power station to be completed by Canada next year.

e. A short-term (3 months) investigation to fully define the scope, time and cost of future studies is necessary. Eminent U.S. experts will be used to aid in reviewing the study plan and technical approaches to resolve this important problem. Cost of this pilot study would be about $60,000 and it can be completed in draft form in 90 days after receipt of authorization to proceed. Study participants would be CERC, WESHH, WES Environmental Laboratory and eminent consultants. It is our understanding that Dr. Greenberg is in Nova Scotia and he has performed additional work on this subject since publication of his thesis. We would discuss this work with Dr. Greenberg and perhaps solicit his expertise and experience in developing the study plan and possibly in completing the future studies.

6. In summary, CERC (in full cooperation with WESHH and WES Environmenal Laboratory) has considerable reservations regarding the use of results from the Greenberg thesis for a decision making basis regarding potential impacts of the highly important proposed tidal power station. A pilot investigation is strongly recommended to develop a comprehensive study plan (scope of work and time and cost estimates) which will, if executed, provide a sound basis for decisions regarding impact of the tidal power station on oceanographic, coastal and environmental parameters in the area. CERC has the mission and expertise to act as the study leader for this pilot investigation and potential follow-on studies. CERC appreciates the opportunity to respond to this highly important challenge to the Corps and the nation.

7. Should any questions arise concerning this evaluation, please contact either Dr. C. L. Vincent or me directly.

FOR THE COMMANDER AND DIRECTOR:

ROBERT W. WHALIN, Ph.D., P.E.
Technical Director

CF:
Commander and Director, US Army Waterways Experiment Station, ATTN: WESHH
Commander and Director, US Army Waterways Experiment Station, ATTN: WESEV

Testimony of

PETER F. LARSEN

My name is Peter F. Larsen. I hold Bachelor and Masters degrees in Zoology from the University of Connecticut, and a Ph. D. in Marine Science from the College of William and Mary. I came to Maine in 1973 as State Oceanographer for the Department of Marine Resources. In 1976 I joined the Bigelow Laboratory for Ocean Sciences in West Boothbay Harbor, Maine where I remain. My research specialty is estuarine and coastal ecology and since 1973 I have concentrated my efforts on the ecological systems of the northern Gulf of Maine.

In 1976, I was approached by representatives of the Passamaquoddy Tribal Council seeking advice on the potential environmental impacts of their proposed Halfmoon Cove tidal power facility. I have intermittantly served as an environmental advisor to that project since that time. In 1979 they asked me to attend a meeting of the Fundy Environmental Studies Committee to learn what I could from the Canadian experience with tidal power and to apply it to the Halfmoon Cove situation. The Fundy Environmental Studies Committee is a group of about 150 scientists involved to various degrees in baseline research on the Bay of Fundy with the general goal of providing data upon which to evaluate the potential consequences of tidal power development to the Bay of Fundy environment.

It was at the 1979 Fundy Environmental Studies Committe meeting that I first became aware of the capability of large-

scale tidal power development at the head of the Bay of Fundy to modify the tidal regime of the Gulf of Maine. As a coastal ecologist, I immediately realized that any modification of the tides would have implications for sedimentary environments, especially fine-grained environments such as mud-flats and salt marshes. At the time we did not appreciate, and probably still don't, the entire suite of consequences that an alteration of Gulf of Maine tides might hold for the New England region. We were intrigued, however, so Dr. Topinka, also of the Bigelow Laboratory, and I attended the 1980 meeting of the Fundy Environmental Studies Committee. This time we came away impressed that:

1) the potential for tidal power development at the head of the Bay of Fundy was being very seriously evaluated;

2) the predictions that such development would result in a modified Gulf of Maine tidal regime were held in high regard by the scientific community; and

3) no serious consideration was being given to possible consequences of a modified tidal regime along the long, highly developed New England coastline.

By this time we were convinced that any modification of the tidal regime would have diverse and far-reaching environmental and socio-economic consequences over a large area. Due to the fine tuning between the tides and the coastal ecosystem, including several aspects of human life, we knew that any comprehensive evaluation of the potential consequences would be very complex and have to involve specialists from several disciplines. We therefore concluded that a prudent approach would be to assemble

a multi-disciplinary team of experts to do an initial evaluation of the long list of potential consequences that we had produced with the aim of culling out the unlikely or insignificant consequences and high-lighting those which seemed to deserve further investigation. During the winter and spring of 1980-1981 we unsuccessfully approached several state and federal agencies in an effort to secure funding for such an endeavor.

In our opinion, the lack of interest in the potential environmental consequences of Fundy tidal power development exists in the United States partly because both the plans for development of Fundy and its possible impacts are not well known. Skepticism concerning construction feasibility has been fueled by a 60 year history of tidal power proposals which have never come to fruition. Some skepticism also exists concerning the ability of a Bay of Fundy barrage to alter the Gulf of Maine tidal regime. For these reasons, much of our effort has been in public education, describing the basis of the Greenberg model and explaining the intimate relationships between the tides and coastal uses and functions.

In June 1982, the Bigelow Laboratory was awarded a scoping contract from the Maine State Planning Office to evaluate the environmental implications of Fundy tidal power development to the coastal resources of the State. This work represents the first formal effort to assess the far-field effects of tidal power development. In addition to Bigelow personnel, individuals were involved from the Provincetown Center for Coastal Studies, the University of New Hampshire, the University of Rhode Island,

Arthur Lerman Associates and the Mahoosic Corporation.

The objectives of our project were threefold:

1) to determine all the environmental consequences, both positive and negative, that are deemed even remotely possible by members of the scientific community;

2) to prioritize these consequences based on their probability and relative magnitude of impact on the coastal resources of Maine:

and

3) to outline research needed to increase our predictive capacity.

A final report is expected to be available in the near future.

This hearing and the release of our report by the State Planning Office are likely to generate considerable publicity on the issue. Undoubtedly much of this publicity will focus on the more dramatic, short-term negative impacts and give the impression that our efforts are anti-tidal power and motivated to "stop the Canadians from doing this." I want to make it clear that this is not the case. The northeast region of the United States is heavily dependent on imported oil and we believe that tidal power may represent a very attractive alternative We also realize that there is an environmental cost to pay for any type of energy. Our efforts are directed at documenting the environmental cost associated with Fundy tidal power generation so that this "non-polluting" energy source can be objectively compared to nuclear and coal-fired generation of electricity, the two leading alternatives to tidal power in New England. We believe

that after some insight is developed concerning the degree of environmental modification caused by the altered tidal regime, tidal power may be viewed as acceptable relative to other methods of generating electricity. We should emphasize that many of the environmental changes anticipated can be considered beneficial.

Thorough investigation of the far-field effects is also in the best interest of Fundy tidal power development. It will be difficult to raise investment capital if environmental questions remain unanswered. Costly delays in construction could also result if environmental intervention develops later due to a lack of information. Clearly, no one loses and everyone gains by timely, comprehensive evaluation of the issue.

One might ask "why is there environmental concern about a tidal modification?" Concern about the far-field effects has largely been played down in Canada by such arguments as: the change in tides is small on an already large tidal range; the change is only equivalent to a small wave on top of the existing high tide level; minor surges due to atmospheric pressure changes are larger than the projected tidal range increases; and, such little change will be lost in the noise.

We contend that the predicted changes in tidal regime are not the equivalent to almost random changes, as those induced by discrete meteorological events. There will be a permanent change in the tidal base upon which all other influences will fall. Although the change may be "lost in the noise" of a short-term record, there will be a shift in tidal base observable over longer time periods. The percentage change in tidal regime will be

larger in the more developed, western Gulf of Maine than in the Fundy region. When one considers the length of coastline affected it is easy to visualize that even a small effect accumulated over such a large area would be grounds for concern.

The problems associated with small-scale, long-term sea level rise in many parts of the world demonstrate that even small changes in the land-sea interface can be of environmental significance. While these changes, roughly 3 mm per year in New England, are small compared to annual variations in sea level (perhaps 18 cm) and meterologically induced level changes, they are undirectional and have historically resulted in the loss of coastal land and structures through erosion and flooding. Whereas the Fundy proposal will not change sea level, it will elevate the high tide line (e.g. high mean water) which, in terms of coastal planning and management, is the effective sea-land boundary. If one can accept that there are environmental problems associated with long-term rise in sea level, it must be clear that the predicted rise in high tide level will also have environmental consequences associated with it.

One of the principle differences between the phenomena of sea level rise and enhanced tidal regimes resulting from Fundy tidal power development is the rate of change. To date, the natural rise in mean sea level is essentially imperceptible on a scale of day-to-day or year-to-year human activity. Geological and biological systems have been able to adapt gradually. By comparison, the proposed tidal range increase will be relatively

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rapid and therefore potentially more disruptive The effective rise in the land-sea interface associated with Fundy tidal power development is equivalent to 50 or more years of natural sea level rise. In addition, there are phenomena related to the predicted tidal regime change which would not necessarily result from sea level rise alone. These include, but are not limited to, a lower low tide level, a larger intertidal zone, stronger tidal currents, and increased estuarine flushing. It is clear that unanswered questions as to the direction, magnitude and socio-economic significance of the possible environmental alterations warrant a major evaluation of the far-field effects of Fundy tidal power development.

Very recently, new projections of future sea level rise have become available. A study funded by the U.S. Environmental Protection Agency predicts that mean sea level will rise due to thermal expansion 2 to 10 feet by the year 2100. At the very least this represents almost twice the rate of natural sea level rise experienced in recent history. The Gulf of Maine has also experienced a marked increase in tidal range in the last 4,000 years. This increase appears to be continuing at a rate of about 3 mm/year or 30 cm (1 foot) per century. This rate should accelerate as some function of the increased rate of sea level rise. In other words, the New England coastline may experience very dramatic natural changes over the next century due to global patterns in sea level change. These changes will have serious socio-economic impacts. The consequences of tidal regime changes caused by Fundy tidal power construction need to be evaluated in

the context of the global changes. Indeed, it may be wise to reevaluate the engineering and economic feasibility of Fundy tidal power in light of the projected sea level changes.

I will now briefly consider some examples of the types of environmental consequences that may be expected if the tidal range was increased by 30 cm as predicted. My colleagues testifying today will discuss other examples and many more are contained in the documents I will submit in evidence. Our purpose is to demonstrate the range of coastal habitats, uses and functions that might be influenced by a small increase in tidal range. We will use examples from the State of Maine where we have had the most experience. This should not imply that serious consequences will be limited to Maine.

One of the most obvious consequences of a higher high tide is the loss of terrestrial habitat. The loss can be due to submergence or to erosion Dr. Graham Giese of the Provincetown Center for Coastal Studies has developed a hypsometric curve for the State of Maine and was able to estimate that a 15 cm increase in high tide level would result in the submergence of 4,200 acres in Maine. This is equivalent to approximately a 2.5 meter wide strip along Maine's coastline. At any given point, of course, the width of the strip lost to submergence would depend on local topography.

Using Old Orchard Beach, Maine, as an example, Dr. Giese was able to extimate the profile retreat of 20 m would result from a 15 cm increase in high tide level.

Loss of terrestrial habitat and retreat of beach faces,

together with increased storm damage should a storm surge coincide with the modified high tide, are fairly spectacular impacts which will directly affect the value of coastal property. There are other less dramatic consequences, however, which will still have a significant economic or aesthetic impact. For instance, the storm sewer system of parts of Portland, Maine has a very low head. It has been predicted that this head will not be adequate at the modified high tide level and "several million dollars" will have to be spent to retrofit the system. Erosion is considered to be the worst current threat to the archaeological sites of coastal Maine. Because of man's tendency to settle on coasts and the naturally rising sea level, over half of Maine's identified archaeological sites are on the coast and will ultimately be flooded. In the short-term, Dr. Arthur Spiess of the Maine Historic Preservation Commission believes "...a 6-inch tidal amplitude increase would be a disaster." He estimates as many as 700 shell heaps and other coastal sites, over 30% of those known exist in Maine, would be lost due to the predicted tidal regime changes. It would cost about 5.5 million dollars to excavate the sites before barrage construction.

An example of an easily overlooked consequence of unknown magnitude concerns the use of bridges. Will the new tidal regime mean some fixed bridges will be impassible by small craft at high tide? Likewise, will the new tidal regime require more frequent openings of draw bridges? While these questions may appear inconsequential relative to major concerns, they could be of significant local impact.

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Although most attention is given to the consequences of higher high water, lower low water will also have effects on coastal uses and functions. Many small New England harbors and boat basins are presently marginally useful at low tide. A 15 cm reduction in the low tide level will further impede boat traffic at times of low tide and could require increased dredging of harbors or scheduling of activities by fishermen and pleasure boaters. We have observed many piers which will have to be extended in order to remain useful at low tide.

There are many diverse consequences associated with the absolute change expected in tidal range. One of the most obvious is that the intertidal zone will be larger. This could lead to an extension of shellfish beds and increase macroalgal productivity, but also raises questions of property boundaries. The location and thickness of the interface between saltwater and overlying freshwater in coastal groundwater systems is influenced by the tidal cycle. Put most simply, the depth of freshwater under a given point of land thickens and thins with the tides. Dr. A. L. Tolman of the Maine Geological Survey believes that an increase in tidal range coupled with increasing year-round development along the coast will result in more severe and perhaps more widespread saltwater intrusion problems.

One result of the projected absolute change in tidal range is an increase in the tidal prism of embayments and estuaries. Larger tidal prisms produce more rapid flushing, temperature dampening and greater pollutant assimilation capacity, all of which might be perceived as beneficial. On the negative side, greater flushing could result in reduced larval retention and altered estuarine zonation. It should be noted that our preliminary calculations indicate that the increase in flushing rate will not be great, perhaps 10%. This is less than the change now experienced over a spring-neap tidal cycle. We believe, however, that there may be an integrated effect over time and that even these relatively small physical changes could cause major biological modifications in certain unique situations. For example, Merrymeeting Bay, one of the largest tidal freshwater wetlands in the United States, is presently protected from large salt water intrusions by a sill at its entrance. Is a 10% increase in tidal prism enough to allow the salt wedge to spill over the sill and change the bay into an oligohaline system? Such a change would certainly have major socio-economic repercussions. More detailed studies are needed before we can realistically evaluate the significance of tidal prism changes

The above examples are limited to effects directly associated with changing tidal levels. Another suite of concerns is related to changes in tidal currents. These will be addressed in part by my colleagues.

As is often the case with a new technology, or one applied at greatly different scale than previously, there are many more questions about the potential environmental impacts of Fundy tidal power than there are answers. We believe the report forthcoming from the Maine State Planning Office represents an important first step in identifying areas of significant concern and should prove very useful to agencies trying to formulate responses. However, this report is only a beginning. Much research is needed. In my opinion, which I believe will be shared by the project's proponents, environmental research should proceed before substantial investments are made in design or construction aspects. In this way, if studies indicate that the net environmental consequences are unacceptable, vast amounts of money and effort can be saved. If studies are begun in the near future, I am sure many of the environmental questions can be resolved without causing debilitating delays in the project.

We are fortunate in some areas to have both the scientific expertise and necessary data bases available to address some potential problems very quickly, i.e. within a year or two. For example, the question of how significant are the projected changes in estuarine flushing rates. This must be addressed on an estuary by estuary basis because of their individual characteristics. An estuarine flushing model is operative at the Bigelow Laboratory. Information on flow rates, volume and tidal ranges of the various estuaries is also available. The model could be run for each Gulf of Maine estuary, the output field checked and the results interpreted in perhaps eighteen months.

Some insight into the significance of increases in current velocity could be gained by examining longterm tidal cycles. Tidal currents may vary by as much as 5% over some of these cycles and at least some fishery biologists believe the cycles in fishery landings are correlated. Long-term tidal records, temperature records and catch statistics exist and could be analyzed for relevant correlations by the proper experts. This could produce an early indication of the potential impact of current changes on fisheries.

Another useful exercise that could be accomplished quickly is a detailed case study of one or more coastal communities. A group of experts including a geologist, ecologist, hydrologist, civil engineer, waste water engineer, real estate appraiser, etc. could walk the shore and assess changes that may result from the advent of Fundy tidal power. A rather accurate dollar value could be assigned to the potential changes in that community. This value could then be used to estimate a total cost of possible damage or mitigative measures over a wider area.

Other information gaps will require a longer time to fill. For example, the relationships between increased tidal mixing, primary productivity and fisheries are complex. Significant progress has been made in recent years but much remains to be done. Large multi-investigator projects of the sort required to address problems of this magnitude may take five to seven years before anything approaching a definitive answer can be attained. Indeed, any predictions concerning large-scale biological systems will always be surrounded by a great deal of uncertainty.

POTENTIAL ENVIRONMENTAL CONSEQUENCES OF TIDAL POWER DEVELOPMENT SEAWARD OF TIDAL BARRAGES*

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ABSTRACT

Recently, the world economic climate, mainly due to fossil fuel costs, has become increasingly favorable to tidal power development. Several potential tidal developments are presently being considered including two massive projects in the upper Bay of Fundy. Although tidal power is nonpolluting in the traditional sense, it does have several environmental consequences, both inside and outside of the tidal impoundment, that warrant detailed evaluation. This presentation gives a preliminary consideration of the environmental consequences of Fundy tidal power development on the Gulf of Maine and the coast of northern New England.

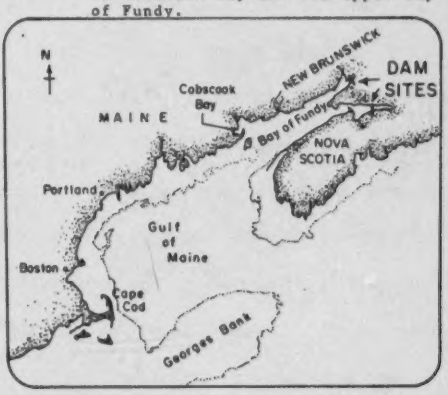
INTRODUCTION

In the last decade, the increasing costs of fossil fuels and concern about the public safety of nuclear power have spawned a growing interest in alternative sources of energy. Where oceanographic conditions are appropriate, a considerable amount of this interest has been focused on large-scale tidal power development. Tidal power has several advantages over conventional energy sources. It is a renewable source of energy that is not influenced by seasonal water levels, floods or droughts as is conventional hydropower. Although most operational modes only produce power on an intermittent basis, and therefore, tidal power facilities must be integrated with other systems, power production is predictable years in advance. Since it uses no fuel, problems associated with fuel acquisition and waste product disposal are avoided.

Potential sites for tidal power development must fulfill two basic needs. First, a tidal range large enough to produce a sufficient head is required. Secondly, the embayment to be impounded must provide a large surface area, while its connection to the sea should be relatively narrow to minimize construction costs. On a worldwide basis, there are generally considered to be about fifty sites suitable for development (1). Presently, the 240 MW LaRance project in France is the only major operational tidal power facility. Other major projects have been considered since early in this century, but development has always been postponed because the high construction costs have invariably outweighed the benefits of low-cost power production when compared to the cost of development of other energy sources. Presently, however, the world economic climate, especially in terms of energy costs, seems to be more favorable for tidal power development and several projects are receiving attention around the world.

In the northwest Atlantic, interest in tidal power development centers in the Gulf of Maine - Bay of Fundy system. American efforts are now concentrated in Cobscook Bay, Maine (Fig. 1). The Half-

Fig. 1 The Gulf of Maine Region. Tidal power projects are being considered in Cobscook Bay and the upper Bay of Fundy.



*Contribution No. 81012
Bigelow Laboratory for Ocean Sciences

Reprinted from OCEANS, September 1981

CH1685-7/81/0000-0908 $00.75 © 1981 IEEE

Moon Cove project, a 12 MW development advanced by the Passamaquoddy Tribe, has undergone lengthy feasibility studies and could enter into final liscensing procedures in the very near future. Other, much larger, proposals for Cobscook Bay are being considered by the U.S. Army Corps of Engineers, but it is not clear how quickly they will proceed. Current Canadian attention is focused on the upper Bay of Fundy (Fig. 1), where the potential for projects in Cumberland Basin and Minas Basin is being studied (Fig. 2). These would be large facilities, being rated at 1,085 and 3,800 MW respectively (2), which is roughly equivalent to one to four nuclear plants. They would address regional power needs, including those of the northeastern United States.

Whereas tidal power is non-polluting in the traditional sense, it does have several environmental consequences that deserve detailed evaluation early in the planning phase (3, 4). These environmental consequences can be conveniently divided into those that occur within, or in the immediate vicinity of, the impoundment and those that occur well outside the impoundment. I refer to these effects as internal and external consequences, respectively. Internal consequences are principally those associated with local current changes and restricted water exchange between the tidal basin and the open sea. Examples are altered sedimentation patterns, loss of intertidal habitat and water quality modifications (5). These effects, which are generic to tidal power development, and by definition, are geographically limited, are the focus of most impact considerations.

External consequences, on the other hand, occur seaward of the tidal barrier and may influence a considerable geographical area. The exact effect depends upon the size and location of the barrier within the entire tidal system. In some cases, such as the defunct U.S. - Canadian project involving Passamaquoddy and Cobscook Bays, the effect would be caused by reduced frictional dampening because of decreased water exchange. Tidal ranges would be affected by about 1% with a maximum increase of 0.7 ft. occurring at the head of the Bay of Fundy (6). In other cases, where barriers are to be located near the end of a closely resonant basin, tidal modification could be significant, the actual change being determined by whether, and to what degree, resonance is enhanced or decreased.

The proposed Fundy tidal power development will enhance the natural tidal resonance of the Bay of Fundy and Gulf of Maine by shortening the basin, bringing its period closer to the natural period of the tidal wave (7). Far-reaching changes in tidal patterns and hydrography could result. Present estimates indicate that an increase in tidal range of from two to thirty cm. would be produced from the southern Bay of Fundy to south of Boston, Massachusetts (7). The increase in range will depend on which project is constructed, but if more than one is built, the effects are expected to be additive (7).

The consequences of altering the tidal regime of northern Gulf of Maine are legion, diverse in scope and range widely in time-scale of development. To date, although the work of Greenberg and others has produced sophisticated numerical models of modifications in tidal behavior induced by tidal power development in the upper Bay of Fundy, little attention has been given to consideration of the resultant environmental consequences. In this presentation, I will address some of the most obvious environmental concerns. It is not my intention to be comprehensive or definitive, but only to begin a dialogue that will help to insure that environmental concerns are given adequate evaluation on a time-scale to allow maximum possible mitigation of projected impacts.

ENVIRONMENTAL CONSEQUENCES

The environmental consequences of tidal power development seaward of the tidal barriers can be categorized as those caused principally by the changes in tidal range and those caused principally by changes in tidal currents. These categories are obviously different manifestations of the same phenomenon, but since tidal range effects will be most pronounced at the coastline, and tidal current effects will be felt over a wider area, it is a convenient distinction for the purposes of discussion. It should be noted that mean sea level remains unchanged.

Effects of Tidal Range Changes

The predicted increases in tidal range will cause alterations in the extreme upper and lower portions of the intertidal zone, that productive region of shoreline which is alternately covered and exposed by the sea. Even modest changes in tidal range will mean that points near the present tidal extremes will be submerged or exposed on a more frequent basis. This will lead to a restructuring of the resident biological communities near high and low water. These communities are finely tuned to, and limited by, the rhythmic pattern of immersion and submersion. The best

example is perhaps the salt marshes which can be large in extent and which exhibit marked zonation of community types over a limited vertical gradient, i.e. large horizontal distances are associated with small elevation changes. The zonation is caused principally by the dominant plant's tolerance to submersion - plants tolerant to frequent submersion living at lower tidal heights and less tolerant plants dominating at higher tidal heights with intolerant plants completely excluded from the tidal zone. The projected increases in tidal range will increase the frequency of ununda tion and, over an undefined period of time, result in an upward i.e. shoreward, movement of plants of the intertidal zone. The higher water levels at mean high tide will reach elevations not previously inundated and marsh plants will displace terrestrial vegetation. In effect marsh area will be increased along landward borders. Analogous effects will occur in all intertidal habitat types and also at the lower end of the tidal range where more hardy intertidal species will replace specialized subtidal forms in the expanded lower intertidal zone.

A significant expansion of the tidal range also could have implications for the human population. Higher tides, as noted above, will cause the loss of terrestrial habitat at the immediate shoreline. The absolute loss will depend on the type, slope and wave exposure of the shore. It may be of no consequence on steep rocky shores, but could be significant in low-lying areas.

Manmade structures, such as piers, docks, low-lying roads and bridges, designed for existing high tide levels will be more closely approached by the higher modified tides. This consequence could take on great importance when a storm surge accompanies an enhanced spring tide and lead to increased property damage for a storm of given magnitude. There is some suggestion, however, that the higher tidal range will reduce the amplitude of storm surges (8). Beach erosion, already a problem in southern Maine, could be accelerated especially if storm waves associated with the higher tidal levels are able to undercut sea walls designed for present tidal levels. The increased tidal levels could, in local situations, cause water table fluctuations and lower the quality of well water in the immediate coastal zone.

Depending on the extent of tidal range alteration, reduced low tide level could also have human impacts. In many small New England harbors, navigation is already difficult near low water and many docks and piers are marginally useful at periods of low tide. Reduced water levels could aggravate this situation reducing boating access and/or necessitating dredging or extending piers into deeper water.

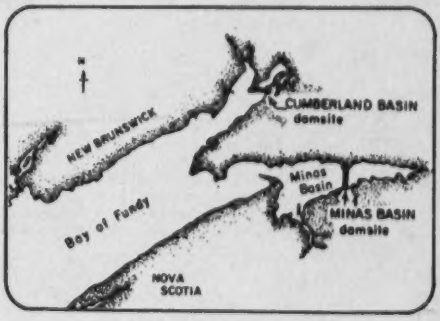
Effect of Tidal Current Changes

Predictions of changes in tidal currents are more difficult to make (9), and hence projections of environmental consequences are on less firm footing than those based on tidal range changes. Yet, changes in tidal currents can have profound and far-reaching effects on the entire Gulf of Maine including Georges Bank. It has been predicted that a large Fundy power development could increase tidal currents in the Gulf of Maine by 5% (9).

In the nearshore environment, an increase in current strength will undoubtedly affect the dynamic equilibrium of sedimentary structures such as intertidal sand and mud flats, subtidal bars, shoals and channels. If these effects are large enough, intertidal clam and worm resources may be impacted and dredging may be needed to keep shipping channels open. Of course, these environments will become re-stabilized in a period of time after a new equilibrium is established.

Increased current strength will modify the flushing characteristics of northern New England estuaries. Especially in the deep-silled estuaries such as the Sheepscot, this could have a pronounced effect on the seasonal temperature range, pollutant assimilation, nutrient supply and hence, productivity. Estuarine faunal communities may be further influenced by a reduction of larval retention within the

Fig. 2 The upper Bay of Fundy and the approximate locations of proposed tidal power facilities in Cumberland and Minas Basins.



estuaries.

Perhaps the most far-reaching consequence of tidal current modification in the Gulf of Maine is the potential change in mixing characteristics. Garrett and his colleagues (9, 10) predict a slight expansion in the well-mixed areas and a reduction in stratification elsewhere. The decreased stratification could result in an increased supply of nutrients to the surface waters and a 1°C decrease in summer surface water temperature with a corresponding decrease in air temperature (9). Ultimately, this could result in an increase in primary productivity of the Gulf of Maine. Whereas changes in primary productivity should be reflected in secondary productivity, it would be premature to comment on how specific fisheries might be affected. Undoubtedly, a decrease in temperature will benefit certain species, inhibit others, which directly or indirectly require some threshold temperature for feeding or reproduction, and have minimal or no effect on others.

Toxic red tide blooms have become common along the northern New England coast in the last decade (11, 12). The increased tidal currents, and reduced stratification, could likely result in greater persistence of the oceanic frontal systems which develop in the northern Gulf each summer. Red tide blooms are often associated with frontal systems (13) and an increase in their size or duration could have negative implications for certain fisheries. Reid (14) correctly notes the necessity of studying dinoflagellate ecology as part of any tidal power environmental assessment.

In summary, I have given a preliminary account of some possible environmental impacts of Fundy tidal power development on the northern New England coast. Some consequences are apparently detrimental, while others are seemingly beneficial. Our understanding of the magnitude of these complex, interrelated problems is embryonic. Indeed, every subject I have mentioned here, and a multitude that I have not, needs indepth evaluation by scientific experts so that decision makers can have the maximum benefit of knowledge of the potential environmental consequences of tidal power development.

ACKNOWLEDGEMENTS

The ideas expressed in this paper are not solely those of the author, but were derived from discussions with several persons to whom I am most grateful. The advice and support of J.A. Topinka and N. Laberge are especially acknowledged.

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Preliminary Evaluation of the Environmental Consequences of Fundy Tidal Power Development to the Resources of the State of Maine[1]

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A Report to the Maine State Planning Office

July 1983

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Note: The following has been excerpted from the above named report. The report in its entirety has been retained in committee files.

Executive Summary

Background

The extraordinary tides in the Bay of Fundy/Gulf of Maine, ranging in some areas from 33 to 45 feet, are one of the natural wonders of the world. For generations, small tidal mills have operated along the coasts of New England and eastern Canada. Over the past half century, these tides have attracted interest as a potential power source for hydroelectric generation. Proposals have ranged in size from the 1,800 megawatt (MW) Passamaquoddy Bay project, investigated by the United States and Canada through the International Joint Commission between 1956 and 1961, to the current 12 MW project at Half Moon Cove on Cobscook Bay in Washington County, conceived by the Passamaquoddy Tribal Council.

Until recently, none of these projects had proceeded beyond the planning stage. During the summer of 1983, a $46 million, 20 MW tidal power plant at Annapolis Royal on the southwestern coast of Nova Scotia is scheduled for completion. Not only will this be the first operating tidal power facility in the Western Hemisphere, it is also a pilot project to test hydroelectric turbines and the feasibility of large-scale tidal development elsewhere on the Bay of Fundy.

Minas Basin Project

In 1982, the Bay of Fundy Tidal Power Review Board, a joint undertaking of the Canadian federal government and the provinces of New Brunswick and Nova Scotia, issued its revised report, Reassessment of Fundy Tidal Power. The Board concluded that Minas Basin on Cobequid Bay

in Nova Scotia presents the most viable opportunity for large-scale tidal power development in the Bay of Fundy. The report recommends construction of a 4,028 MW plant to produce an estimated 12.6 billion kilowatt hours of electricity annually, 90% for marketing in the U.S.

The $22 billion project would necessitate construction of a barrage five miles across Cobequid Bay from Economy Point to Cape Tenny. The Board's economic evaluation of the project determined that such a plant would have a benefit/cost ratio of 2.6-3.0 under present economic conditions. While construction costs are the major impediment to the project's initiation, changes in economic or energy supply conditions could alter these circumstances and facilitate development of the Minas Basin project.

Effects of Minas Basin Development on the Maine Coast

The same unique oceanographic conditions which presently result in the large tides in the Bay of Fundy and throughout the Gulf of Maine also create an unusual situation whereby construction of the Minas Basin project would produce significant tidal effects along the entire coast of Maine.

Canadian projections indicate that the project will increase the "tidal range" in the Gulf of Maine by approximately 10%. This will result in high tides approximately 6 inches higher and low tides 6 inches lower, from Eastport to Kittery.

Because this change could have enormous impacts upon the environment, economy and people of Maine, Governor Joseph E. Brennan requested that the State Planning Office (SPO) begin an investigation of these potential effects and report to him with recommendations for

further action, including the need for additional, detailed scientific analysis. In 1982, the SPO contracted with Bigelow Laboratory for Ocean Sciences to conduct a preliminary evaluation of the environmental consequences of Fundy tidal power development on the resources of the State of Maine.

On the basis of the Canadian projections for tidal range and current amplification, this report concludes that the Minas Basin project would have physical, geological, biological and socio-economic consequences of potentially great significance to Maine.

This report identifies issues of concern, reviews available information and determines priorities for future research. The findings contained herein are preliminary and constitute neither a complete nor a final assessment of the effects of Minas Basin development. Additional, detailed investigation and analysis are necessary to determine precise impacts upon specific areas and resources.

Physical and Geological Consequences

Through land submergence, higher mean high tides will result in the loss of a strip of land averaging 8 feet in width along the entire coast of Maine. This would amount to a loss of 4,200 acres of coastal property and terrestrial habitat.

This shoreline retreat will vary considerably, depending upon the slope of specific areas affected. Rocky shore communities will restabilize quickly, while marshes and mudflats will take several years to adjust. Along the flat sandy coast of York County, some beaches could retreat by more than 60 feet over the next 50 years.

This expansion of intertidal area could eventually create up to 1,700 acres of new marshland after restabilization, an increase of 10%. Erosion due to greater ice cover in marshes, however, could limit some of this additional marsh formation. In the short-term, however, high marsh areas would be routinely flooded, possibly resulting in extensive biological changes.

Increased tidal fluctuations would cause the saltwater wedge underlying coastal aquifers to rise. Fully one-quarter of Maine's coastal communities will experience a decline in drinking water quality due to the intrusion of saltwater into groundwater aquifers.

The increased tidal range would alter sedimentation patterns in tidal inlets. Natural inlets bounded by erodible borders would become wider. Inlets bounded by man-made jetties would become deeper and wave action within harbors would increase.

Because the 6 inch increase in high tides would add to potential storm surges, the number of storms which damage the coast would more than double. A storm of the magnitude of the 1978 nor'easter that caused $47 million in losses, and which now occurs about every 100 years, would be expected to occur about every 25 years.

The higher tides would cause more frequent flooding of low lying areas. The increased flooding, coupled with swifter tidal currents, would result in a faster coastal erosion rate, especially for beaches.

Swifter tidal currents could lower summer water temperatures along certain coastal regions by as much as 1°C. This would result in lower air temperatures, a greater incidence of fog and stronger onshore winds.

Biological Consequences

The physical and environmental effects of the Minas Basin project would have a variety of effects upon coastal marine and terrestrial biology. Without more detailed study, it is difficult to determine the absolute magnitude of these changes; however, some general trends are clear.

The higher tides and swifter currents will result in greater flushing of estuaries. This could have several effects, both positive and negative. The larvae of shellfish and other species would be dispersed over a greater area. This could lead to lower spat set in some traditional shellfish beds. It may, however, result in the colonization of productive new areas, and the reseeding of still other areas which have been depleted or spoiled by past pollution. These conditions could also enhance the growth of phytoplankton, macroalgae and marsh grasses. Higher current velocities would, however, make spilled oil more difficult to contain. Increased flushing would also be beneficial in the event of pollution discharges, however, as the flushing would cause faster dispersal.

Tides have significant effects upon the organisms which cause the "red tide" phenomenon. Increased tidal velocities would not only create a more conducive environment for the development and growth of these organisms, they would also transport the organisms further and faster, increasing the likelihood of red tide blooms.

Higher tides would bring greater quantities of seawater into estuaries, possibly disturbing the natural balance for certain plant and animal species. These effects would be site specific, but an ecologi-

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cally sensitive area, such as Merrymeeting Bay, could witness dramatic changes.

Lower summer water temperatures will have detrimental effects on various plant and animal species which approach their northern limit in Maine waters. Such animals include the American oyster and horseshoe crab. The migratory patterns of certain fin fish species like bluefish and menhaden, could change due to lower water temperature. The predicted merging of circulation patterns over Georges Bank and Nantucket Shoals could also produce significant changes in local fish distributions. Higher tides and swifter currents would also enhance the growth of barnacles and other "fouling" species which damage physical structures and vessels.

Socio-economic Consequences

The physical and biological effects of Minas Basin would have significant impacts on the economy and culture of Maine. While coastal areas would receive direct impacts, the entire State can expect to share in the results of these effects.

The loss of useful land, due to the increased tidal range, and the real or perceived effects of damage from more frequent storms and flooding, will decrease the value of some coastal property, especially in southern Maine. Insurance costs and actual damages in such areas would total millions of dollars. Diminished property values could result in reduced property tax revenues in some communities.

The addition of new intertidal area, however, including new beach and clam flats, will enhance values in some communities. The faster

dispersion of pollution would also benefit the environment and the economy and tend to offset other effects of the Minas Basin project.

Maine would also benefit in that a new, predictable, environmentally clean source of energy may become available which could replace some of Maine's dependence on fossil fuel and nuclear power. While the amount of electrical power available to Maine and its cost remain uncertain, large amounts of low cost electrical energy would be extremely attractive.

Coastal tourism and recreation, which are vital to the State's economy, could suffer from poorer weather conditions such as increased fog, stronger sea breezes and lower water temperature.

These meteorological effects, coupled with the lower low tides and swifter currents, will have ill-effects on marine transportation. Docking and mooring will be more difficult, and the potential for accidents could increase. These factors will also impede navigation, resulting in greater fuel consumption. Harbors may be altered by changes in patterns of sedimentation, and structures, such as piers and docks, will be subject to more damage from storms, wave action and "fouling" organisms.

The tides, storms and currents will affect many roads, bridges, seawalls and various other physical structures. Some, like the bridge at Rutherford Island in South Bristol, may have to relocated or reconstructed. Others will be subject to greater damage. The costs to the local State and federal governments could total millions of dollars. Intrusion of saltwater into wells and effects upon services such as sewage treatment facilities would have serious implications for local governments along the coast.

Effects on fishing are difficult to anticipate without further investigation. Increased intertidal area, nutrients and pollution assimilation may be beneficial to some species, especially shellfish. However, shifting beds and the dispersal of larvae could dislocate many productive shellfish beds. Increased occurrence of red tide will restrict catches and may have significant economic effects.

The lower water temperature at the surface in summer may limit the catch of some finfish. In some areas, swifter currents will make fishing more difficult and raise fuel consumption. These costs, plus damage to vessels and structures from storms, wave action and "fouling" species, could cost fishermen millions of dollars.

Offsetting these effects is a potentially greater supply of food due to increased plant growth both in coastal and offshore areas. Such increased productivity could translate into greater fish catches of food limited species.

This report seeks to put forth, in an objective manner, some of the major implications of Fundy tidal power construction, without making value judgements. There are clearly, however, both positive and negative consequences which must be explored and weighed by the State.

Recommended Actions

An examination of the potential effects of an increased tidal amplitude on Maine emphasizes our need to know more about the fundamental mechanisms that are important to estuarine and marine systems. It is important to realize that a knowledge of the environmental effects is basic to our understanding of major economic

influences and must be considered together with socio-economic effects. The following presents a list of primary and secondary recommendations.

Primary recommendations

1. In order to adequately explore tidal power issues, it would be helpful to facilitate the exchange of ideas between experts in many fields. It is suggested that a two day symposium be sponsored to consider both scientific and socio-economic issues and that this meeting be open to the public.
2. Increases in intertidal area will occur as the result of higher tidal range. It is necessary to know how much the various intertidal habitats will be increased in terms of area. How much area will be lost from subtidal and terrestrial borders? What is the response time of the various sedimentary environments? How will the gains the losses be distributed among various segments of the coast?
3. What will be the biological responses to the above changes? What will the new equilibrium be and what will be the implications for commercially and aesthetically valuable biological components?
4. Using the Greenberg model, an attempt should be made to asses tidal current velocities and their attendant influences on vertical mixing processes in the Gulf of Maine. What changes in surface and bottom mixing will take place?
5. The environmental and socio-economic consequences of Fundy tidal power development must be evaluated in the context of the very recent postulations of rapidly accelerating sea level rises.

6. Many economic impacts can be identified at this time. Case studies in two or three coastal communities should be made by a multi-disciplinary team to develop a deeper understanding of the economic consequences to various sectors of the community.

Secondary recommendations

The following presents a list of questions that should ultimately be addressed:

1. How will patterns of productivity and pollution dispersion be altered?
2. What changes in water mixing and circulation will take place?
3. To what extent will the temperature of surface waters change?
4. What degree of present biological variability is associated with natural variability in tidal cycles?
5. How quickly will the tidal regime change during tidal power construction?
6. What will be the extent of increased storm damage?
7. What will be the extent of damage to structures and facilities from routine high water flooding?
8. To what extent will saltwater intrusion of wells be exacerbated?
9. Who could be held legally responsible of monetary damages incurred? How can damages be demonstrated to be a result of Fundy tidal power development?

Part I: Introduction

Purpose of Study

Oceanographic modelling undertaken as part of the planning process for Fundy tidal power development indicates that the tidal regime of the entire Gulf of Maine could be altered. Modification of the tidal regime will have profound effects on the physical and biological processes active in the coastal zone. These modifications, coupled with the naturally occurring rise in sea level, and the natural increase in tidal range, will have serious environmental and economic implications in the decades ahead. The degree to which the environmental changes on the Maine coast can be accurately anticipated will determine the extent to which economic damage can be avoided or reduced.

The principal goal of this report is to provide knowledge necessary for the prediction of environmental alterations associated with tidal power development at the head of the Bay of Fundy. This information is required for the multitude of large and small decisions which must be made concerning the varied uses of the coastal zone. Do we locate a road or a building at a certain elevation or, given the knowledge of the rising sea level and increasing tidal range, do we prudently locate it a foot or two higher? This is an example of a situation where foreknowledge of environmental conditions can make the difference between a certain economic disaster in the near future and an investment which will realize its full potential. Other decisions have to be made concerning disposition of public and private lands, waste disposal, fishery and agricultural developments, groundwater resources, etc. These routine decisions have to be made regardless of whether or not Fundy tidal power becomes reality. The decisions might be slightly

different, however, if Fundy development is considered. Low, or no cost, alterations in planning decisions made at this time, in light of the potential for Fundy tidal power, may save untold money and hardship in the future.

The utility of the present exercise is not lost if the decision is made not to go ahead with Fundy tidal power. Due to naturally rising sea level and increasing tidal range, many, if not all, of the far-field environmental consequences now identified with Fundy tidal power development may ultimately be realized. It is, therefore, prudent to consider what their manifestation implies for the coastal resources of Maine. It must be remembered, however, that the changes associated with Fundy tidal power development will occur in addition to natural changes and hence will accelerate and exacerbate the environmental consequences.

The first tasks in making decisions on environmental problems are to identify the problem and quantify the impacts. These are the specific goals of this report. To the extent possible, we have identified the specific environmental consequences of Fundy tidal power development on the coastal environment of Maine. We have given initial consideration to the entire spectrum of potential environmental changes, both detrimental and beneficial, which are deemed at all possible by the scientific community. We have put these environmental consequences into a socio-economic context and have suggested further research to reduce the predictive uncertainty surrounding many of the more important issues.

The far-reaching and basic nature of tidal interactions with the coastal zone produces a study area of amazing scope when the tidal regime is changed. The major limitation of this study is the short time available to evaluate all of the aspects of the problem. Thus, few areas were researched to the complete satisfaction of the scientists

involved or the users of the report. This limitation is offset somewhat by the setting of priority areas of study, such as potential for increased erosion and changes in biological productivity, by the State Planning Office and other interested agencies. Even so, few of the issues raised could be completely resolved.

Another major limitation of the study involves the lack of fundamental understanding of several basic processes in the Gulf of Maine. Reliable predictions of tidal power consequences cannot be made when the normal situation is poorly understood. Much basic research is needed in the Gulf of Maine if this and other impending environmental impacts are to be accurately anticipated.

The Advent of Tidal Power

The generation of electricity by turbines turned by tidal water is a concept that may be coming of age. A century ago many coastal mills were driven by tidal energy but the practice was discontinued with the development of engines and inexpensive fossil fuels. However, rising energy costs resulting from increased fossil fuel costs, along with concern about the safety of nuclear power, has sparked a renewed interest in developing tidal power resources. Tidal energy has several advantages over conventional energy sources. It is a renewable source of energy that is not influenced by seasonal water levels, floods, or droughts as is conventional hydropower. Although most operational modes only produce power on an intermittent basis, requiring tidal power facilities to be integrated with other systems, power production is predictable years in advance. Since it uses no fuel, problems associated with fuel acquisition and waste product disposal are avoided.

Although interest in the potential for tidal power has been manifested periodically, there has never been such a high degree of activity as there is today. The 240 MW LaRance project on France's Brittany coast has been successfully producing electricity since 1967. Other sites are presently being evaluated along the coasts of Brittany and Normandy. The British are continuing their consideration of the Severn Estuary barrage and have already completed extensive environmental studies. Major sites in Argentina, Australia, India and Korea have received preliminary evaluations and a demonstration project has been built in Russia.

In North America, interest in tidal power is high in the Gulf of Maine-Bay of Fundy region (Fig. 1). There are at least three projects being studied on the United States side of the border. The Passamaquoddy Indian Tribe has done extensive studies on the potential for a 12 MW tidal unit in Halfmoon Cove in Perry, Maine. Also in Cobscook Bay, the U.S. Army Corps of Engineers is evaluating several possible tidal dam configurations and operating modes. A very small, private initiative is underway in central Maine on the island of Vinylhaven and, if construction begins in 1983 as is possible, this could result in the first active tidal power plant in the U.S. In addition, the Maine Office of Energy Resources and State Planning Office are surveying the Maine shoreline to determine its potential for small scale tidal power development.

The vast majority of North American interest in tidal power during the last two decades has been focused on the upper Bay of Fundy. The first tidal power plant in the western hemisphere will go on line at Annapolis Royal, Nova Scotia in the summer of 1983. This project

consists of a 20 MW low head Straflo turbine fitted into a pre-existing barrage. Its purpose is to demonstrate the utility of the turbine in the marine environment. Construction costs using this type of turbine are 10-15% less than those associated with more conventional low head turbines, so the success of this pilot project could have a significant impact on the feasibility of large scale developments. Several sites for large scale tidal power developments have been studied in the upper Bay of Fundy. For the last two years extensive and intensive technical, economic and environmental consideration has been directed at one site, designated B9, in the Minas Basin (Fig. 1). This site, with a potential capacity of up to 6,000 MW, may be the world's first "mega-project." It is the focus of this report.

Tidal power theory and operation

The concept of tidal power is simple. In its most basic form (Fig. 2), an impoundment is allowed to fill on the rising tide through filling gates or sluices. When the tide reaches its maximum height the sluices are closed. As the tide falls, the tidal pool is held at this level until a sufficient water level differential, or head, develops between the tidal pool and the sea. A head of about two meters is considered a minimum. At this point, the impounded water is drained from the pool through turbines which generate electricity. This process continues as the tide ebbs as long as sufficient head exists. Near low tide the turbines are closed and, when the rising tidal level equals the level in the pool, the sluices are opened and filling commences again. This process is repeated with each tide, i.e. 705 times a year.

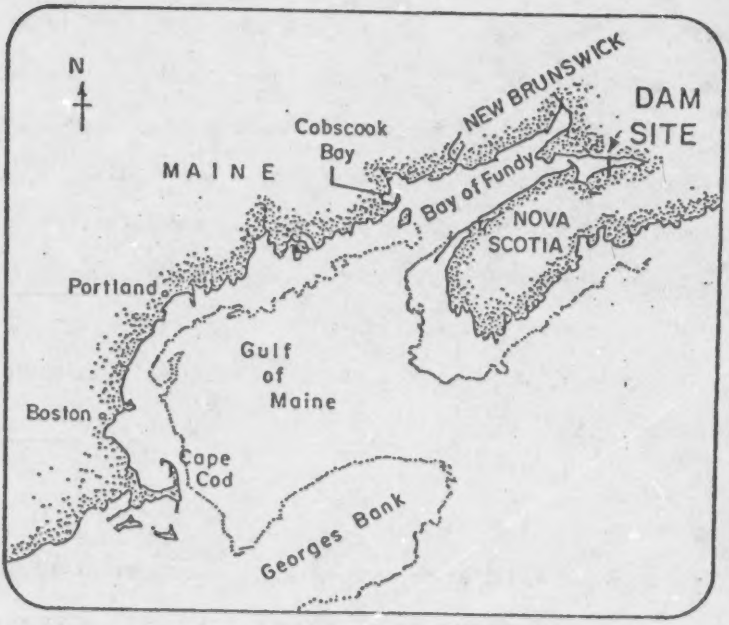

Fig. 1. The Gulf of Maine-Bay of Fundy region.

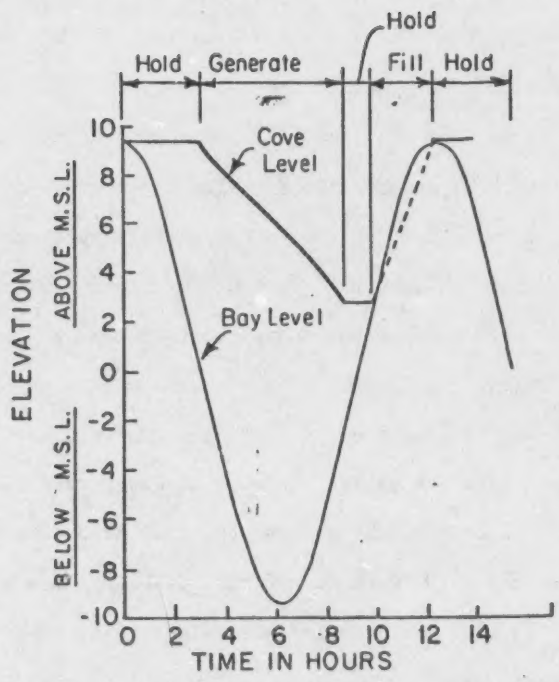

Fig. 2. Operating phases of a single effect, high pool tidal power facility.

The above operation is called a single effect, high pool system; single effect means that power is generated only on one phase of the tide and high pool indicates that it is the water level of the impounded pool is maintained higher than instantaneous sea level. This is only one of several operating modes that can be used singly or in combination with one another. It is, however, the most commonly proposed operating mode because it is the most inexpensive to build and the easiest to operate. Its major disadvantage is that electricity is produced only about 50% of the time and production is often out of phase with demand.

A single effect, low pool operation is created when the gates are closed at low tide allowing the level of the sea to exceed the level in the basin. Electricity is generated by running water through the turbines from the sea into the basin. This procedure produces less electricity than a high pool system because the head cannot be controlled. The environmental effects are also probably less desirable. Its major advantage is that the production of electricity is 180^{o} out of phase with a high pool system. Therefore, a low pool operated in conjunction with a high pool, can generate electricity almost continually. A recent feasibility study showed that if a low pool system were to be built in one of the several arms of the Cobscook Bay to complement the proposed Halfmoon Cove high pool system, electricity from tidal energy would be available 96% of the year.

With the use of reversible turbines a double effect tidal plant can be realized. Here, electricity is generated on both the rising and falling tides. Production ceases only near the turning points of the tide when little or no head exists. Due to the physics of the system a double effect operating mode produces less total energy than a single

effect high pool system, but the production is more nearly continuous and, hence, is more easily integrated into an electrical grid. The major disadvantage of a double effect system is the higher cost of the more sophisticated turbines. This results in about a 20% increase in the cost of electricity. The one major existing tidal facility in the world today, the LaRance project in France, has double effect capability although it has been operated as a single-effect high pool since about 1978.

The above are the three basic operating modes of tidal power plants. Several variations exist. The actual operation may be very complex and involve switching of operating modes to better couple production to demand or to take maximum advantage of tidal periodicities.

For further information on the tides and tidal power the reader is referred to:

Introduction to Tides: The Tides of the Waters of New England and New York by A.C. Redfield (Marine Science International)

Tides and the Pull of the Moon by F.E. Wylie (Stephen Greene Press)

Tidal Energy by Roger Henri Charlier (Van Nostrand Reinhold)

Short Background on the Proposed Fundy Project

The extremely large tides and topography of the basins at the head of the Bay of Fundy, as well as their relative proximity to power markets, make these sites ideally suited for tidal power development. Several sites in the upper Bay of Fundy have been evaluated at various

times for almost 20 years. In 1969, the Atlantic Tidal Power Programming Board (ATPPB, 1969) concluded that tidal power was not economically feasible under the existing conditions but that it might be if:

1. interest rates dropped;
2. a breakthrough occurred in construction costs or turbine costs;
3. pollution abatement requirements magnify the costs of alternative sources; or
4. alternative sources become depleted.

By 1972 sufficient changes had occurred in these factors and a major evaluation study was instituted by the governments of Canada, New Brunswick and Nova Scotia. The conclusions of the resulting 1977 report (Fundy Tidal Power Review Board, 1977) showed that at least two sites, B9 in Minas Basin and A8 in Cumberland Basin, had a benefit to cost ratio of 1.2 and therefore were approaching economic viability. Since 1977, technology, energy regulation policies and energy costs have changed even further. Interest and support for tidal power development has also shifted from New Brunswick to Nova Scotia. The need to raise capital has turned attention from the Cumberland Basin site, most highly recommended by the 1977 study, to a larger Minas Basin facility which can produce excess power for export and encourage U.S. investment.

An update of the economic portions of the 1977 report was funded in 1981. This report, entitled "Fundy Tidal Power Update '82" (Tidal Power Corporation, 1982), contains the most favorable economic forecast for tidal power to date. Three factors contribute to this:

1) obviously, but not exclusively, the increased cost of energy generated by other methods.

The value of tidal power is not that it replaces the need for construction of other generation plants, but that it replaces fuel costs. It is only the displaced fuel costs that are used in the economic comparisons.

2) changes in marketing strategies.

In 1977 it was assumed that the electricity should be used principally in the Maritimes. This assumption was changed in 1982 allowing projections of energy needs and fuel costs in New England and New York to be used.

3) design changes.

Tidal power is capital intensive because of construction costs. Advances in turbine technology and modified construction procedures can shorten the construction period and produce electricity two years before the date projected in 1977.

Using conservative figures for energy needs, the cost of alternative fuel and construction costs, the 1982 report found the most efficient system to be a 4800 MW plant with the power distributed 10% to the Maritimes, 45% to New England and 45% to New York. The benefit to cost ratio then falls between 2.6 and 3.0 which makes this an economically attractive project.

The one remaining hurdle seems to be raising capital. Construction cost is 6 billion in 1981 Canadian dollars. Current interest levels (1982) increase the cost to 22 billion dollars over the 10 year construction period. To raise this money, proponents of tidal power must compete in a capital limited economic climate with other proposed large scale energy projects including increased nuclear options, hydropower in Quebec and offshore gas. In the next decade or two it would seem likely

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that only one of these major energy resources could be fully developed. At this time, it is not clear which resource that will be. Supporters of tidal power, however, believe Fundy tidal power economics are so favorable that it is a question of when, not if, the power potential of upper Bay of Fundy will be harnessed.

Oceanographic Setting of the Gulf of Maine

Present conditions

In order to appreciate the environmental implications of Fundy tidal power developments to the State of Maine, it is important to understand the Gulf of Maine and its tides. At the sea surface, the Gulf of Maine has the shape of a great horn, extending northeastward from the bottom of its broad mouth at Cape Cod to its split tip at the head of the Bay of Fundy (Fig. 1). But its sea surface shape is deceiving. Not far beneath the surface, three vast barriers - Browns Bank, Georges Bank and Nantucket Shoals - extending together in a broad arc from the Hatteras/Cape Cod Shelf to the Scotian Shelf, separate much of the Gulf's water from to the open Atlantic Ocean. As a result, the Gulf of Maine has some characteristics of an inland sea. Its only deep water connection with the Atlantic Ocean is the Northeast Channel, which is approximately 40 km wide and lies between Georges and Browns Banks. The much shallower Great South Channel separates Georges Bank from Nantucket Shoals.

Among the Gulf's most striking characteristics is its tidal regime. Tidal range increases continuously from its mouth to its head where, at Burntcoat Head in Minas Basin, the largest mean tidal range in the world, 11.7 m, is recorded. The extreme vertical changes in tide level

in the upper Bay of Fundy provide the potential for the economical extraction of large amounts of hydroelectric power.

Because of their great amplitude, the Gulf of Maine/Bay of Fundy tides have long interested oceanographers. Like coastal tides everywhere, the Gulf of Maine tides are not the direct result of the tide-producing forces of the moon and the sun. These forces do act directly on the water of the Gulf, of course, but the total mass of the Gulf of Maine is too small for much energy to be transferred in this manner. Rather, the source of the Gulf's tidal energy lies in the tidal regime of the open ocean. The mean range of the Atlantic tide at the mouth of the Gulf is less than one meter. Its major constituent is the lunar semidiurnal, or M_2, constituent which has a period of 12.4 hours.

The key to understanding the vastly greater tides within the Gulf of Maine/Bay of Fundy system lies in the fact that the system's "free" period of oscillation is close to the 12.4 hour period of the semidiurnal tide. By the "free" period of a system is meant the period at which it will oscillate naturally if first given a push and then left alone. Just as the free period of a pendulum's swing depends upon its length, so the free period of a body of water depends upon its geometry, its horizontal and vertical dimensions. Of course, when pushed not once, but regularly, as the Gulf of Maine is by the ocean tides, the body of water oscillates, not at its own "free" period, but at the period of the pushes, the "forced" period. However, when its free period is close to, or the same as, the forcing period, energy is retained within the system and the amplitude of the oscillation becomes large. In this condition, called "resonance," only a relatively small amount of input energy is needed to maintain the large oscillations.

Resonance has been postulated by a number of investigators as an explanation for the large tidal ranges in the Gulf of Maine/Bay of Fundy system. Proudman (1953) calculated the free period of the Bay of Fundy alone to be 11.1 hours and assumed that it was forced by semidiurnal tides at the mouth of the bay. Later, as a result of studies by Rao (1968), Duff (1970) and Garrett (1972), it was found that Proudman's calculated free period was too large for the Bay of Fundy alone, and that the Bay of Fundy and the Gulf of Maine combined to form a single oscillating system. Garrett (1974) calculated the fundamental free period of this system to lie between 12.4 and 13.0 hours. The most recent estimate is that by Greenberg (1979) who found the free period of the Gulf of Maine/Bay of Fundy system to be about 12.5 hours.

Summarizing, tidal range increases by more than a factor of 10 from the mouth of the Gulf of Maine to its head in the upper Bay of Fundy. This great amplification is the result of near-resonance between the fundamental free period of oscillation of the Gulf of Maine system, approximately 12.5 hours, and the period of the open ocean tide which forces it, 12.4 hours. It is especially significant that the free period is greater than the forcing period (Garrett, 1974), for the free period can be reduced by the construction of a tidal barrage at the head of the Bay of Fundy resulting in increased resonance and therefore enhanced tides.

Greenberg model

Dr. David A. Greenberg of the Bedford Institute of Oceanography, has studied the Gulf of Maine/Bay of Fundy tidal regime, and the affect of tidal power development on it, for many years (e.g., Greenberg, 1969,

1975, 1976 and 1977). His recent paper, "A Numerical Model Investigation of Tidal Phenomena in the Bay of Fundy and Gulf of Maine" (Greenberg, 1979) updates the earlier work. Using the finite difference method, he applied the equations of continuity and motion through a grid with progressively smaller mesh size from the lower Gulf of Maine to the upper Bay of Fundy. Coriolis acceleration and quadratic friction terms were included. The open boundary input consisted of a pure M_2 tide with the characteristics based on historical and recent data. The coefficient of friction and the depth of the Gulf of Maine were adjusted to produce the best fit to observed tides at 74 stations. It was the model goal to match observed tides within 15 cm. for amplitude and 5° for phase, and this goal was generally met.

Predicted tidal range changes

It is to be expected that if the dimensions of the Gulf of Maine system were altered, as they would be by the construction of barriers for the purpose of hydroelectric power development, the tidal regime would also be altered. The barriers would reduce the size of the Gulf of Maine-Bay of Fundy tidal basin and therefore the free period of the system. Since the existing free period of the system is nearly resonant with, and slightly greater than, the M_2 forcing period, the barriers would be expected to cause an increase in tidal range throughout most of the system. In order to evaluate such effects, Greenberg ran his numerical model as calibrated, with modifications introduced to simulate the changes due to proposed barriers. In the case of a barrier which encloses Shepody Bay, the model showed an increase in tidal range for the Maine coast of less than 10 cm. However, a barrier in the upper

Minas Basin would increase the range by 28 cm at Portland Harbor and 30 cm at Boston (Fig. 3). For the purposes of this study, it will be assumed that an increase of 30 cm would occur along the entire coast of Maine. This represents approximately a 10% increase in tidal range.

How realistic are the predictions based on the Greenberg model? This question is central to the concern about Fundy tidal power. It is also not a simple question, and a complete answer to it is beyond the scope of this project. During our interviews (see Methods section, below), modellers were asked their opinions of the adequacy of the model and the accuracy of its predictions. The Greenberg model is held in very high regard in the scientific commuhity, and criticism of it tended to be on a detailed rather than conceptual level. A letter requesting evaluation of the model and three representative responses are included as Appendix I. It should be noted that several of the suggestions for improvement, such as a finer grid size and studies of residual currents have been done or are in progress.

Over what period of time would this increase occur? In answer to that question, asked in reference to the tidal hydroelectric facility presently proposed for the upper Minas Basin, Mr. George C. Baker, Executive Vice-President of the Tidal Power Corporation, estimated that the increase would take place gradually (although not steadily) over a period of approximately 5 years as construction gradually blocked tidal flow. Thus we calculate, as a first approximation, that tidal range would increase along the coast of Maine at a rate of about 6 cm per year, and that the mean high tide level would increase at a rate of about 3 cm per year, over the 5-year period. Dr. H.G. Tolland, a

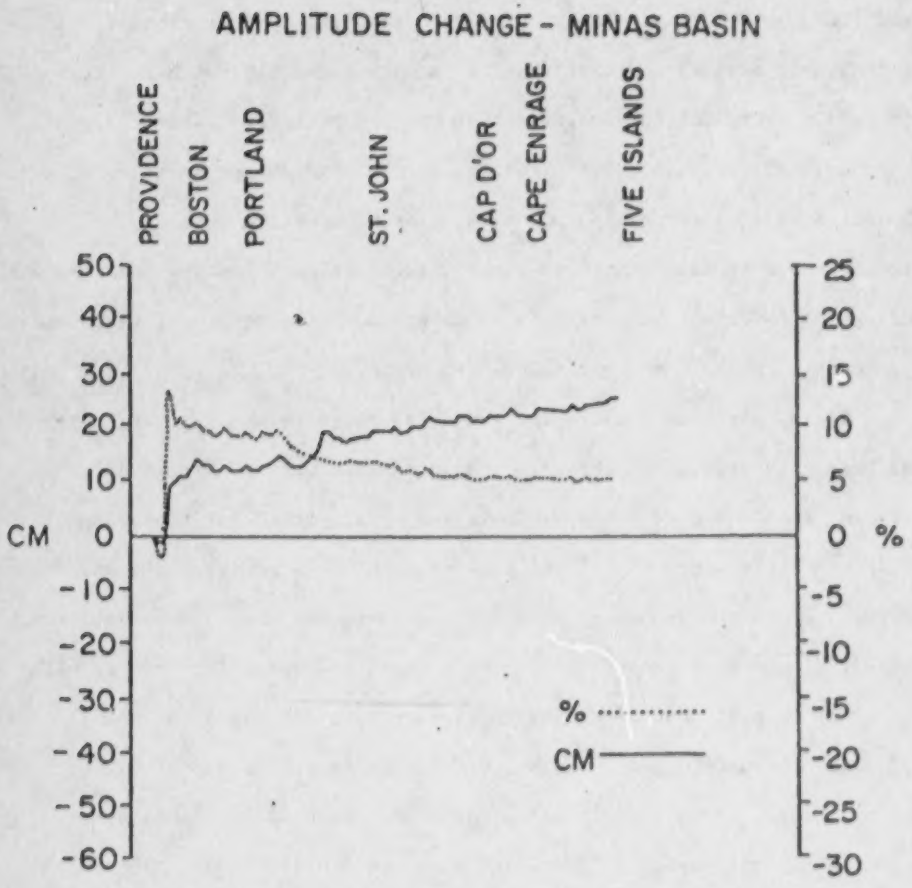

Fig. 3. Predicted absolute and percentage change in tidal amplitude in Gulf of Maine. Note that amplitude is equal to one half the range (modified from Fundy Tidal Power Review Board, 1977).

modeller on the Severn estuary project has a slightly different opinion, although it must be realized that he is not as familiar with the Fundy proposals. Dr. Tolland suggests that the tidal changes will approach a threshold effect, i.e. during construction little change in tides will be noted until a certain point during closure when the system will suddenly and rapidly switch to another equilibrium. Knowing the rate of change is important because it will determine the severity of response of several physical and biological processes.

It is useful to compare the above figures with the existing rates of mean high tide level change. Sea level data derived from tidal records obtained over an approximately 50-year period for the coast of Maine indicate a mean sea level rise of about 3 mm per year (Hicks, 1974). Since the mean high tide level experiences the same change, the effect of the Minas Basin construction would be to increase ten fold the existing rate of mean high tide level rise for a period of 5 years.

It should be noted that this comparison is valid only as a long term average. Variation in annual mean sea level of $\pm$ 3 cm is not unusual for the coast of Maine, and a similar level of variation is usual between monthly mean sea levels (Permanent Service for Mean Sea Level, 1977).

Predicted tidal current changes

As tidal range is increased, tidal currents will also increase as a larger volume of water will be moved. While accurate predictions do not exist for the increase in tidal currents, current change may well be on the same order as for tidal range, i.e. about a 10% increase for much of the Maine coast. Increased tidal currents, resulting from an increased

tidal amplitude, encounter friction as they move over the bottom. Some of this tidal current energy becomes dissipated as turbulence or mixing. In regions which become stratified, an increased tidal current velocity could increase mixing of surface or bottom waters. Decreases in summer surface water temperature on the order of 1°C (Garrett, 1977) might result from enhanced, but not dramatically altered vertical mixing (Garrett et al., 1978).

Bigelow
Laboratory
For
Ocean
Sciences
A DIVISION OF NORTHEASTERN RESEARCH FOUNDATION, INC.

24 August 1982

Dr. H.G. Tolland
Energy Technology Support Unit
Building 156
AERE Harwell
Oxfordshire OX11 ORA
UNITED KINGDOM

Dear Dr. Tolland,

The Bigelow Laboratory has recently been commissioned by the Maine State Planning Office to do a preliminary environmental assessment of the potential impacts of Fundy tidal power development on the resources of the State of Maine. While the principal thrust of our investigation will be ecological and socio-economic in nature, the reliability of the numerical modelling of the Gulf of Maine tidal system, and its modification by the proposed project will have a bearing on all aspects of our work. Mr. George Baker of the Nova Scotia Tidal Power Corporation has given us your name as someone with sufficient knowledge to comment.

As you are aware, Dr. David Greenberg of the Bedford Institute of Oceanography has produced a numerical tidal model which predicts that construction of the Minas Basin tidal barrage will increase the tidal range in the western Gulf of Maine by 30 cm (Greenberg, D.A., 1979, A Numerical Model Investigation of Tidal Phenomena in the Bay of Fundy and Gulf of Maine. Marine Geodesy 2: 161-187.). We are using these predictions for our projections of the ecological consequences but would appreciate your expert opinion on their reliability so we can portray the potential impacts with realistic confidence intervals. Specifically, do you believe the model is correct in predicting enhanced tidal resonance in the Bay of Fundy-Gulf of Maine system? Are the magnitudes of projected tidal range increase reasonable? How reliable are the projections at the model's boundaries? What could be done to improve the projections, if necessary?

Many laypeople have difficulty accepting the tidal predictions and call for a second, independent modelling effort. Many oceanographers, on the other hand, are satisfied with the way the model fits the existing conditions and believe further modelling is not necessary. Do you

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Bigelow Laboratory for Ocean Sciences

believe that it would be beneficial for U.S. interests to independently model the system and, if so, how much would it cost and how long will it take?

A major environmental concern is the impact of storm surges on top of the higher tidal levels. There has been discussion that it may be possible to dampen the effects of storm surges by opening all the turbines and sluice gates and thereby mitigate the impacts. From your experience do you believe that a tidal system the size of the Gulf of Maine could respond quickly enough that storm surge damage could be mitigated in this way?

Your comments on these questions will help us greatly in our efforts and will help to define future research needs should the Fundy project continue to develop.

Thank you very much for your consideration.

Sincerely yours,

Peter F. Larsen

Peter F. Larsen, Ph.D.
Senior Research Scientist

PFL:po

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Telephone: Abingdon (0235) 834621
Extension 278
Telex: 83135

Date 20 September 1982

Dr P F Lawson
Senior Research Scientist
Bigelow Laboratory for Ocean Sciences
McKown Point
West Boothbay Harbour
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USA

Dear Dr Lawson

FUNDY TIDAL POWER - NUMERICAL MODELLING

Some of the questions which you raise in your letter of 24 August concerning Mr Greenberg's model are similar to those which concerned us at the outset of the Severn Tidal Power studies. Like you, we used the results of the models in assisting us with various impact studies.

Our studies made use of models developed at the Institute of Oceanographic Sciences and the Hydraulics Research Station. There was close integration of the work of the two groups of modellers, with IOS concentrating on remote effects and the impact of any tidal range alteration on energy output and HRS concentrating on the flow patterns in the estuary. HRS relied on IOS predictions of remote effects. The models were fundamentally the same in terms of the governing equations and the manner of solving them. The Greenberg model is similar to the IOS model, indeed he started work on it while at IOS.

I have consulted with oceanographers at IOS and HRS to seek their views on the Greenberg model. Their views confirm those of the oceanographers you mention; they are satisfied with the way that the model fits the existing conditions and believe further modelling is not necessary. The Fundy system has now been studied in great detail, probably rather more than in the Severn. Boundary conditions now take account of the effects of the Atlantic Ocean, the model itself going out to the edge of the shelf. The process of validation both at the coast and shelf edge for Fundy gives confidence that the model has homed in the right behaviour. All this amounts to a pretty thorough investigation.

It is accepted that the enhanced resonance is correct and that the model is close to the right anser in magnitude. The accuracy of the model tides is probably correct to within a few percent in amplitude and the phases are quite good. Dr Greenberg no doubt has a good idea of the probable accuracy and could advise you on confidence limits.

Neither I, nor the oceanographers I have spoken to, believe that it is necessary to develop an independent model. It would probably be better to have the Greenberg model examined by an independent export if you believe there are sufficient doubts to warrent this. To develop an adequate model from scratch would take one to two years with costs in the region of £100,000 (based on commercial rates in the UK). If you are able to use a pre-existing model then it might only be necessary to insert the Fundy geometry, and then calibrate..

Mr P F Lawson

20 September 1982

This could take around three months. After model development, test runs could be carried out at the rate of one to two tests a month, depending on the complexity of the test.

I can only give a qualitative answer to your question concerning storm surges. The resultant tidal amplitude is made up of the incoming tidal wave and the reflected wave from the barrage. The expected increase in tidal amplitude is ude to the reflection from the barrage and any modification of the barrage by, say, [illegible]ing all sluices and turbines open would modify this reflected wave and le[illegible] to a rapid response. There are however two problems:

- to kill off the reflected wave entirely would mean removing the barrage: opening all sluices and turbiens would only knock out part of the reflection, ie reduce but not eliminate the enhanced tidal range.
- the influence of the barrage travels at a velocity of $\sqrt{gd}$ where d is an average depth. This suggests that it would probably be some hours for it to get say several hundred km to the areas of concern to you.

The response of the system could be readily modelled and it may well be worth your commissioning Dr Greenberg to carry out a suitable study.

Finally, I would anticipate changes in the patterns of water movement and sedimentation could well be important to your environmental impact studies. This is certainly the case for our Severn Studies. The 30 cm change of tidal range implies relatively modest changes in velocity. However, sediment transport depends on a high power of velocity, something like the fourth power. Also, the shape of the tide curve will change. Both these factors suggest a change in the nett sediment movement. I understand Dr Greenberg has carried out work on sedimentation changes and this could be worth following up.

I hope these remarks are useful to you. However, if you want further technical information it could be useful to contact Dr Norman Heaps at the Institute of Oceanographic Sciences, Bidston Observatory, Birkenhead L43 7RA, England. Dr Heaps lead the modelling effort at IOD on the Severn and is familiar with Dr Greenberg's work.

Yours sincerely

Heardanby

pp H G TOLLAND
Tidal Power Group

Rand
SANTA MONICA, CA. 90406

15 September 1982

Dr. Peter F. Larsen
Senior Research Scientist
Bigelow Laboratory for Ocean Sciences
McKown Point
West Boothbay Harbor ME 04575

Dear Dr. Larsen:

In your letter of August 24, 1982 you asked many questions concerning the modeling of the Gulf of Maine and the Bay of Fundy which are not easy for me to answer as I am not familiar with the studies performed up-to-now.

My first reaction is that it would have been very difficult to obtain a study of this quality in the United States for reasons which I will explain later.

I have reservations, however, which do not reflect on the work done by Dr. Greenberg. I feel he has been working from an insufficient data base. In my opinion, accurate tide data should be measured at the model boundaries simultaneously with currents in the Gulf and Bay and vertical tides at the significant shore stations. Only when this is done can an actual simulation of the water movements be made as a verification of the model and more insight in the boundary problem can then be obtained.

Dr. Greenberg used navigation charts to describe the bathymetry. This is not accurate. In the modeling investigations for the Netherlands Rijkswaterstaat, we found it necessary to use depth surveys taken at about the same time as the tide data to obtain good results.

The increase in tidal range for Boston, as described in Marine Geodesy for one of the barrier schemes, is larger than I would expect but this increase is still about the same as the accuracy of the computations and, for this reason, more accuracy would be required to find its significance.

Your question as to a separate modeling effort is, in my opinion, dependent upon the potential impact the estimated changes in the regime may have, and, naturally, the possibility that the plan will be executed. If these impacts are considerable then you need to extend the work, but this would only be beneficial if better tide data is available as outlined above.

The cost of such a modeling study is high--my rough estimate would be $1,500,000 to $2,000,000 over a four year period, and this would not include the field work. An engineering study would be required. As you indicate in your letter,

Dr. Peter F. Larsen
Bigelow Laboratory

15 September 1982

oceanographers are generally satisfied when the phenomena are well represented. In engineering studies this is not the case and we have to work much more accurately.

In the beginning of my letter I indicated that it would be difficult to duplicate the study in the United States. Modeling is an art and a science. The art has to be learned and requires experience. Dr. Greenberg was fortunate to have studied and worked in England with one of the most experienced groups in tidal computations. In my own career I have benefitted enormously through my association with the Deltadienst of the Netherlands Rijkswaterstaat.

In the United States the main tool in estuary studies has been physical models and no pioneering work was done to develop the mathematical modeling technology by the responsible agency. A recent overview of present capabilities in the U.S. can be found by reviewing the Proceedings of the First Two-Dimensional Flow Modeling Seminar at the Hydrologic Engineering Center, Davis, California (U.S. Army, Corps of Engineers, March 1982).

As far as reducing tidal height during storms by opening sluice gates, this cannot be answered quickly. Some engineering calculations and simulations would be required and if a model is available then this can be quickly resolved. It should be realized that the operator of the facility would be reluctant to take these steps as loss of energy would be involved and an extensive Operations Research project would be required to set guidelines for operation. For the storm surge barrier in the Delta region of the Netherlands our Corporation had a large research project for several years in which engineers of the Delta Service participated to determine when the gates should be closed.

The varying depth and non-linear effects cause the tide to generate residual currents and this was not discussed by Dr. Greenberg. These residual currents are often important for the ecosystem.

For your information I am enclosing two reports and a paper which may be of interest to you.

Sincerely yours,

Jan J. Leendertse
Engineering and Applied Sciences
Department

JJL:gc

Enclosures: 1. Reprint: *Two-Dimensional Tidal Models for the Delta Works*
2. R-2121/1-NETH
3. R-2444/1-NETH

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Phone: (617) 548-1400
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15 October 1982

Dr. Peter F. Larsen, Senior Research Scientist
Bigelow Laboratory for Ocean Sciences
McKown Point, West Boothbay Harbor, ME 04575

Dear Dr. Larsen:

In answer to your questions concerning barrier-induced tidal system modifications in the Gulf of Maine, I enclose the following comments and assessments.

Dr. Greenberg is a mature and thoughtful scientist; his tidal model for the Gulf of Maine/Bay of Fundy system, while in some respects not "state-of-the-art", has been carefully constructed and shown to approximately reproduce the available tidal observations in this region. I am unaware of any more thorough study of this tidal modification problem than that summarized in Dr. Greenberg's recent papers and reports. In general, therefore, I believe that his qualitative predictions of enhanced tidal resonance are likely correct.

Nonetheless, in view of certain unresolved physical as well as computational issues (such as sensitivity to improvements in model geometry, topography, boundary condition implementation, parameterization of flooding/covering of tidal flats, etc.), I would suggest that the present quantitative predictions of tidal enhancement be treated with caution. In particular, it is difficult to assess the reliability of Greenberg's enhancement figure of 30 cm for the western Gulf of Maine in the absence of prior examination of the above-mentioned issues.

It is technically feasible to construct a tidal model for the Gulf of Maine/Bay of Fundy system with several improvements over existing models - including irregular grid finite-difference or finite-element techniques offering a more accurate representation of coastal boundaries, and improvements in open ocean boundary condition specification and model resolution. Since such a model might be expected to reproduce the qualitative features of Dr. Greenberg's results, its development would only be warranted if improved quantitative predictions of tidal enhancement were required. (This, in turn, depends upon the predictive skill required for management decisions.) The development and utilization by U.S. interests of an independent tidal modelling activity would cost (very roughly) $150,000-250,000, take (equally roughly) two years, and require several half-to-full-time theoretical oceanographers/data processors/programmers.

It may be possible, as you suggest, to partially control the effects and impact of storm surge damage by opening all turbines/sluice gates. The efficacy of such an approach would crucially depend, in turn, on the predictive ability of operational coupled meteorological/storm surge models for the Gulf of Maine region. Given reasonable advance notice of a coming surge, say about 12 hours, corrective action might be taken. This level of predictive skill for surges is presently attainable, but might also require model development of a sort similar to that discussed above.

If I may be of further help, please let me know.

Yours sincerely,

Dale B. Haidvogel

Dale B. Haidvogel
Associate Scientist

DBH:am

Testimony on Tidal Power Issues

June 25, 1983

by

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Bigelow Laboratory for Ocean Sciences
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This testimony will address three areas. Firstly, a perspective will be provided on tides and predicted tidal changes. Secondly, some of the more important biological influences will be discussed. Finally, some major research needs will be identified.

The ebb and flow of tides is an important feature of coastal Maine. An intertidal zone is created between high and low tide marks which supports unique communities of plants and animals that are of considerable biological and economic value. Tides also influence water currents which mix and disperse vital nutritive materials, biological products and pollutants. One has only to motor or sail along the coast of Maine to gain some appreciation of its vast length. It has been estimated that this rugged and convoluted coast supports an estuarine and marine shoreline totaling over 4000 miles and this does not include small scale shoreline irregularities which would add even more length to the Maine shoreline. It is this enormous coastline which is influenced by tidal action.

It has been predicted that the 5 mile long tidal dam in the Minas Basin will increase the 3 m tidal range by approximately 30 cm to produce an increase in tidal range of approximately 10%. Although in relative terms this is not a great change, the significance of an environmental change is not only dependent on the degree or dramatic

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nature of change. It is also dependent on the size of the area affected. This 10% increase in tidal range will be felt along the entire coast of Maine. Thus tidal effects will encompass virtually the entire Gulf of Maine and its shore line. It is this widespread nature of tidal effects that renders them potentially important.

How and to what degree will these widespread tidal influences be manifest? Will such tidal changes and some of the effects they produce be insignificant, to be lost in the natural variability or 'noise' of the tidal system? Consider that this 10% change in tidal amplitude is set against a background of large tide variation between spring and neap tides and atmospheric influences. Isn't this predicted 10% change in tidal range a small, insignificant part of the natural variability of tidal patterns? The answer is a definitive no! This 10% increase in tidal amplitude is not merely part of the natural "noise" of the tidal system. Such a 10% change represents a long term one way shift in tidal range background upon which all other variations are based.

What physical and biological changes would be induced by this 10% shift in tidal range? It is clear that physical and biological components will vary considerably depending upon component type, location, time and other circumstances and that there will be no great uniformity of response.

If we examine natural biological populations we soon discover that they exhibit large natural variabilities. Would tidal effects on such populations be important? Would they be measurable and would it be possible to later ascribe these alterations to an increased tidal range? While some populations may undergo large dramatic alterations, with many biological populations it must be recognized that relatively small

biological changes due to tidal power construction may not be easily discernible. In many complex natural systems it may be difficult, if not impossible, to ascribe an altered population to a change in tidal regime alone.

If, for example, a particular biological population undergoes a 10% increase or decrease in population numbers due to tidal power construction, it may not be easily noticed and interpreted as a tidal effect if such populations naturally undergo 10-20% increases or decreases on a year to year basis. It is probable that such tidal alteration may not become statistically apparent or verifiable as trends for many years. As with the physical shift in the tidal regime, however, such population changes are likely to be real one way shifts in baseline population conditions, and be of real importance in that the mean or average conditions have been altered.

If we examine the coastal region of Maine, we can anticipate many specific changes in physical and biological regimes. The intertidal region will experience some of the most direct effects of an altered tidal range. Firstly, there will be an increase in the width of the intertidal zone creating an increase in intertidal area. It has been estimated that the width of the intertidal zone will be increased by approximately 5.0 m, yielding an increase in intertidal area of 8,400 acres in Maine. The land area that would now be routinely submerged at mean high water would total roughly 4,200 acres. This 4,200 acres of land or a mean strip of land 2.5 m wide, would then be claimed by the sea by a 15 cm increase in mean high water.

The degree to which the intertidal zone will be expanded will depend upon the slope of the shoreline. A 30 cm increase in tidal range

will produce little significant increases in absolute intertidal area on steeply sloping shores, such as many rocky shores. On gently sloping shorelines, such as found on tidal marshes, a 30 cm increase in tidal range may greatly expand intertidal area covered by mean tides.

A change in tidal inundation patterns will also produce some significant changes in the distribution of intertidal organisms. In the intertidal area, plants and animals are often distributed in vertical zones or layers with respect to tidal inundation, due in large part to their requirements or tolerance for exposure to air and associated stresses. The vertical zonation patterns of plants and animals will be altered in several general ways. Firstly, there will be a widening of each vertical band of biota. Where shore slopes are uniform, a 10% increase in tidal amplitude will yield zones that are 10% wider. Many of these zones, however, will also be vertically displaced. Only zones of intertidal biota that inhabit areas at mean water in the middle of the intertidal zone would not be affected. In the region above mean water, biological zones will be displaced up to 10% upwards from mean water. Zones of biota which are below mean water will be displaced up to 10% from mean water. Where suitable habitat is available this displacement and a 10% increase in area would be expected to eventually result in greater biological productivity leading to a 10% potential increase in intertidal biota such as, soft shelled clams, mussels, seaweed and marine worms.

Of all the intertidal habitats, salt marshes are the most vulnerable to a change in tidal regime. The transition between upper and lower salt marsh areas occurs as a result of tidal inundation patterns, where upper or high salt marsh areas are infrequently flooded

and low salt marsh areas are regularly flooded. The transition zone occurs in the vicinity of mean high water. The position of this transition zone, coupled with the great horizontal expanse of gently sloping high marsh makes this upper marsh region highly susceptible to the influence of a 15 cm increase in mean high water. The ratio of high marsh, characterized by Spartina patens, Distichlis and Juncus, to low marsh, characterized by Spartina alterniflora, is approximately 11:1 in Maine. This suggests that the upper marsh area vastly exceeds the low marsh area and will be the salt marsh region which will undergo the most drastic change as low marsh plants take over lower high marsh areas and upper high marsh boundaries are extended landward, thus changing the character of the marsh.

This change in plant populations and attendant changes in marine natural populations may well be dramatic. Maine possesses only approximately 17,000 acres of salt marsh despite its extensive shore line. This renders salt marsh habitat relatively rare and valuable. Salt marshes are well known to produce important regions for various juvenile fishes and provide areas for cover, nesting, rearing of young and feeding of shorebirds. Given time, sedimentary deposition will elevate the level of marsh soil to the point that a new equilibrium is established and salt marshes stabilized. This process may, however, take many years during which many salt marshes may be severely disrupted. In the long term, given proper conditions for expansion, a 10% increase in marsh area is conceivable, where an additional 1,700 acres of salt marsh is created. Erosional processes and physical restrictions may however limit this potential expansion.

An increased tidal range will also result in increased tidal currents in addition to altered patterns of coastal inundation. These

changes in tidal currents are expected to produce some significant changes in many physical and biological components of coastal systems. Increased current velocities will be expected to change erosional-depositional patterns in sedimentary areas such as salt marshes, mudflats and soft bottoms. Many such regions are expected to be eventually reorganized, some in different regions. Such habitats will however eventually adjust to new current patterns and again become relatively stable.

Increased current velocities will also enhance vertical mixing processes and exchanges between estuarine and marine waters. Together with increased plant production due to expanded intertidal areas such water movement processes are anticipated to stimulate primary production of organic food matter by phytoplankton, seaweeds and salt marsh plants. This should lead to a greater secondary production of marine and estuarine animals including commercial species. Such an effect would be highly beneficial. The greater dispersal of biological products such as invertebrate larvae of clams should also prove beneficial.

Increased current velocities may however promote the ingestion of red tide cysts during non-bloom conditions and also lead to greater red tide formation and dispersion. This would contribute to higher levels of red tide contamination of vulnerable shellfish. The growth of fouling organisms, such as barnacles, on marine surfaces could also be increased and ice abrasion and damage would tend to be greater.

As a result of greater tidal amplitudes, the flushing of estuaries would also be improved. Virtually all pollutants entering an estuary would be dispersed and flushed from estuaries at greater rates resulting in "cleaner" coastal waters.

The effects briefly described here are among the most important effects of an increased tidal range. Many more potential influences could be discussed. From this it is clear, however, that both beneficial and detrimental influences are possible. Many will be important but few will be as dramatic as those expected for salt marshes. One would suspect that the casual observer of the coast would notice few major changes and he may be correct. By and large the character of the coast would remain much the same. Subtle changes in biological productivity are however also of considerable importance and must be understood if we are to protect our coastal resources.

In order to adequately evaluate and weigh the beneficial and detrimental aspects of a 10% increase in tidal range, many issues must be addressed in more detail. While some issues can be adequately explored with existing data, other effects may require considerable field work.

As a first step it is suggested that a two day symposium be sponsored to consider both scientific and socio-economic issues. This meeting should be open to the public. This symposium would help to facilitate the exchange of ideas between experts in many fields of concern. A detailed proposal to conduct this symposium has been formulated by the Bigelow Laboratory.

Increases in intertidal area will also occur as the result of higher tidal range. It is necessary to know how much the various intertidal habitats will be increased in terms of area. A detailed work plan has been drawn to address this topic area. How much area will be lost from subtidal and terrestrial borders? How will the gains and losses be distributed among various segments of the coast? What will be

the biological responses to these changes? In particular, to what extent will salt marshes be influenced?

Increased tidal flushing of estuaries will take place, which may increase primary productivity of organic food matter and will disperse pollutants more quickly. To what degree will flushing be changed in various estuaries and how will the systems respond in terms of temperature, salinity, productivity, pollution assimilation and community distribution? A detailed study of this area has also been assembled by the Bigelow Laboratory.

These are among the most important topics which need to be addressed. Such studies should supply much of the information needed to evaluate tidal power influences along the Maine coast.

Bigelow
Laboratory
For
Ocean
Sciences

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26 August 1983

The Honorable George Mitchell
366 Senate Russel Building
Washington, D.C. 20510

Dear Senator Mitchell:

It was our pleasure to offer testimony at the July 25th hearing to consider tidal power issues. In response to your request we have prepared the enclosed document which outlines strategies and investigations for evaluating major New England concerns.

Sincerely,

Louis A. Codispoti
for

Charles S. Yentsch
Executive Director, Bigelow Lab.

Jerry A. Topinka
Research Scientist, Bigelow Lab.

Peter F. Larsen
Research Scientist, Bigelow Lab.

Barry Timson
Marine Geologist, Mahoosic Corp.

JAT:pb
Encl.

PROPOSED STRATEGIES AND INVESTIGATIONS TO EXAMINE U.S. ENVIRONMENTAL IMPACTS RESULTING FROM TIDAL POWER DEVELOPMENT IN THE MINAS BASIN, BAY OF FUNDY

by

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I. INTRODUCTION

Construction of a 5 mile long tidal dam in the Minas Basin, Bay of Fundy is predicted to increase tidal range throughout the western Gulf of Maine by approximately 10% resulting in potentially serious environmental consequences. Knowledgeable oceanographers would argue that many of the physical and biological patterns in the entire Gulf of Maine are to a great extent controlled by the ebb and flow of tides and the water movements they induce. It is our considered view that a 10% change in tidal range represents a significant long-term one-way shift in the entire tidal range background upon which all other tidal variations are based. As such this tidal amplification is different from many other factors which yield tidal range variations but do not shift mean high water or mean low water levels.

Both beneficial and detrimental environmental aspects of an altered tidal range need to be evaluated in order to allow federal, state and local agencies the oppo.tunity to safeguard U.S. interests. This document briefly outlines strategies and topics which should be pursued, and identifies agencies which may provide guidance, support and evaluation for scientific efforts. While many concerns such as detailed fisheries influences cannot be precisely addressed due to lack of scientific knowledge and the complexity of natural systems, we wish to stress our confidence that the scientific community has the capacity to address some of the most basic and important questions surrounding tidal power issues. We would stress that such scientific investigations be conducted by both American and Canadian researchers in close collaboration.

II. CONFIRMATION OF TIDAL PREDICTIONS

Firstly we must point out that we and many of our colleagues hold Dr. Greenberg's model and tidal power predictions in very high regard. It is our view that Dr. Greenberg's model provides the best tidal data for the Bay of Fundy-Gulf of Maine system. We further believe that his model cannot be significantly improved upon without a major program to improve input data and it is unnecessary to formulate another tidal model. We do, however, understand the desire to seek further proof of tidal predictions in view of the magnitude of the issues involved.

The Greenberg model and its tidal prediction could best be verified by having several of the world's leading oceanographers examine and comment on the adequacy and precision of Greenberg's model and tidal predictions. Such an undertaking would no doubt substantiate Greenberg's work in a relatively short time at low cost. We strongly believe that this is the best approach.

In conjunction with this validation we suggest that Greenberg, together with American colleagues, expand the data set upon which his model is based. This would involve gathering more data on a finer "grid" scale to refine and improve the precision of tidal prediction. This would also serve to validate such tidal prediction and provide improved tidal data for other environmental predictions.

III. SELECTED STUDIES

The following presents a brief outline of major topics which may be approached with existing scientific capabilities. Such investigations form an information matrix to produce a conceptual framework with which to understand some major tidal power effects. A more comprehensive list of detailed research projects will be assembled if required.

A. Shore line and bottom alterations

Increased tidal amplitude will tend to result in greater current velocities, higher high tides, greater icing in some regions, greater high water levels during storms, and greater wave energies. Many or all of these factors will act to reshape shore line and bottoms especially in regions composed of soft sediment such as sand or mud. A comprehensive program is needed to examine the movements of sediments both along intertidal shore lines and bottom regions. Such a program should have two components: one component would focus on the accelerated sediment movements resulting from storms while the second component would examine sediment alterations which are induced by expanded tidal range alone.

Representative estuaries should be examined to assess the degrees to which intertidal sand beaches, mudflats, salt marshes and bottom sediments will be reorganized as a result of increased tidal range under non-storm conditions. Field work should include sediment profiling studies which examine shore slope, grain size and erosional-depositional forces. Investigations should ideally examine many of the same embayments as outlined in Section III.C. "Estuarine Ecosystems."

It is necessary to more accurately quantify and define beach recession rates due to tidal amplitude increases alone versus increases in coastal storm surge levels. A more detailed analysis of existing historical recession and storm data is required, as well as recalculations of 100-year storm surge levels and wave run-up profiles to quantify the extent of coastal damage due to the increase in storm surge levels. Flood prone areas and wave run-up profiles should take into consideration expected recession rates not inherent in the new FEMA flood prone area maps. These analyses should be undertaken for the major barrier beaches in Maine where there is an adequate information base of historical recession, flood zone, and storm-related dollar damage data.

Lower low tides and increased beach erosion related to coastal storm processes should also increase the amount of sedimentation and shoaling in both sand and mud coastal embayments, perhaps requiring more frequent dredging. Detailed field investigations of selected harbors in Hampton and Scarboro should be undertaken. These investigations should include an examination of beach profile and volume losses due to storms and related sand body and channel changes in adjacent harbors. Field techniques would include mapping by normal surveying techniques and precise bottom mapping by fathometer and electronic positioning. Each harbor/beach pair will be investigated three times over a two-year period. These data will be compared with historical dredging data obtained from the Corps of Engineers.

B. Shore line ecosystems

The vast coastline of Maine supports many species of plants and animals that are of considerable biological and economic importance. The existing tidal pattern has allowed many species to inhabit specific vertical zones with respect to tidal height and periods of immersion in seawater. A new tidal regime could result in significant shifts in the extent and position of these zones.

It is proposed that the influence of an increased tide range on intertidal shore lines and their biological populations be evaluated. This investigation would profile the present and altered tidal regimes and the distributions of organisms relative to those regimes in major intertidal habitats in Maine. These habitats would include salt marshes, mudflats, rocky shores, sand beaches and gravel shores.

The present tidal regime and its contact with intertidal regions could be examined using time course aerial photography in conjunction with ground level measurements of water height. This intertidal profiling could also be examined at times of extreme high water, equivalent to the altered tidal regime. These measurements will provide data on tidal height, shore slope and intertidal area which will yield an understanding of the ways in which altered tidal regimes will influence inundation patterns. Profiles of substrata derived from transect analysis will provide the necessary data base to determine the recolonization potential in intertidal regions. The distribution of intertidal macroflora and macrofauna will also be examined by transect analysis. Such data will provide information on the intertidal area of various habitats that will be altered in terms of inundation patterns and associated biological populations.

The degree to which different types of intertidal shore line will be influenced by erosional-depositional processes such as increased current velocities and icing will have been evaluated in the work described under Section III.A "Shore line and bottom alterations." The influence of these physical alterations on the production and distribution of biota should be evaluated using anticipated physical changes in shore line characteristics.

C. Estuarine ecosystems

As a result of an increase in tidal amplitude, the waters within estuaries will become more thoroughly mixed. Greater rates of water exchange between estuarine and marine regions will also promote higher rates of estuarine "flushing." This increased mixing and flushing could produce significant changes in temperature, salinity and chemistry. These variations, combined with altered water movements, could yield important changes in biological populations. Pollutants entering estuaries would also be diluted, dispersed and flushed from estuaries at faster rates.

It is proposed that a study be undertaken to examine the extent to which increased mixing and flushing will be increased in different estuaries and embayments on a seasonal basis. We propose that

comparative studies be conducted in the Kennebec, Sheepscot, Damariscotta and Penobscot River embayments. Changes in current velocities, mixing, temperature, salinity and nutrients should be examined on seasonal bases over spring-neap tidal cycles using research vessels and low altitude remote sensing techniques from aircraft. The abundance, distribution and diversity of estuarine plants and animals should also be examined using ground level and remote sensing techniques. These studies will provide fundamental insight into how the physics, chemistry and biology will change in Maine estuaries.

D. Offshore ecosystems

1. Biological production in the Gulf of Maine

Primary production of organic food matter by phytoplankton provides the energy which drives biological growth in the Gulf of Maine. Since vertical mixing of water masses is generated to a large extent by tidal currents, an increase in tide range would generally increase mixing. This increased mixing would bring more nutrients into surface waters to yield higher levels of primary productivity. It is necessary to know how, where and when primary productivity will be changed. This problem may be approached by examining vertical mixing and plankton production by satellite imagery and the use of research vessels. The influence of tidal range could be assessed by studies conducted over spring-neap tidal cycles on a seasonal basis.

2. Biological production in major fisheries regions

Dr. Greenberg's tidal model predicts that there would be a merging of the vertically well-mixed areas over Nantucket Shoals and Georges Bank. Such an event could significantly change current patterns around these productive fishing grounds resulting in altered fisheries production. The finer grid patterns obtained for Dr. Greenberg's model, together with satellite and cruise data, could be used to study plankton densities and water movements across and around Georges Bank and Nantucket Shoals. Seasonal studies over spring-neap tidal cycles would help us understand major changes in productivity which might result from a 10% increase in tidal range.

IV. WORKSHOPS

It is suggested that workshops be sponsored to allow scientists, supporting agencies and other interested parties to exchange ideas and follow scientific progress. Scientific efforts will clearly involve a great number of diverse but interrelated studies. It is essential that all investigators periodically organize their data for presentation to colleagues within the program as well as other scientists. This will also serve to critically evaluate scientific programs.

We envision the need for 5 three-day workshops where all program scientists will participate. These workshops will supplement the more frequent assembly of groups of scientists who collaborate closely.

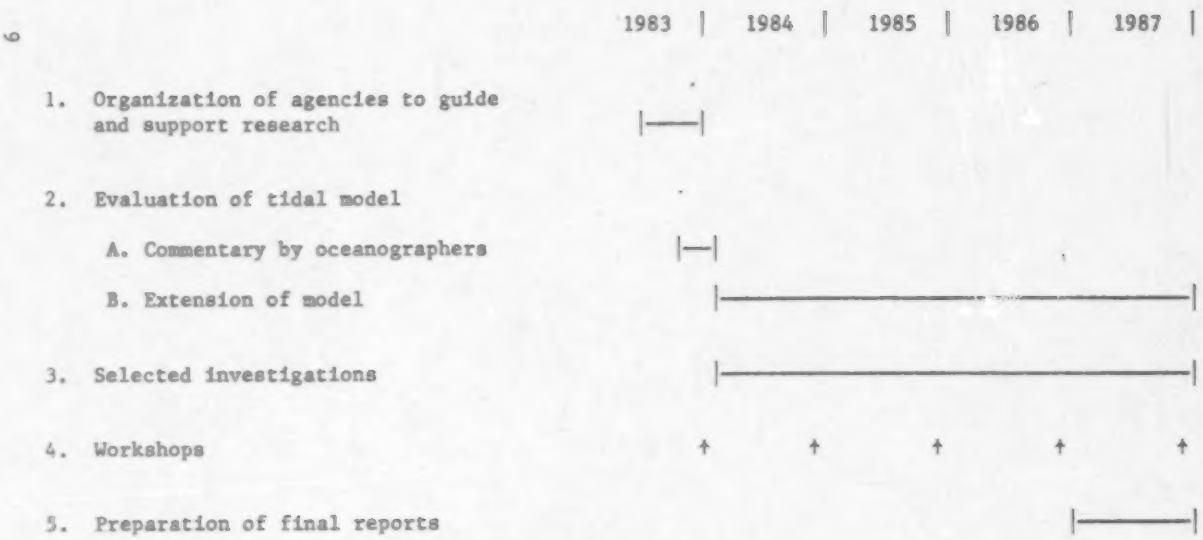
V. AGENCIES TO GUIDE, SUPPORT AND EVALUATE SCIENTIFIC STUDIES

It is of critical importance that all scientific efforts be well planned, adequately supported and critically evaluated. We suggest that a committee be established by the National Academy of Sciences to organize and oversee the scientific research. Spencer Apollonio, Commissioner of the Maine Department of Marine Resources, is in the process of having Governor Brennan request the National Academy of Sciences to establish a committee to guide this research. Charles S. Yentsch, Director of the Bigelow Laboratory for Ocean Sciences, has already contacted the Academy and has indicated that the Academy would be willing to establish such a committee.

Research support might be handled through NOAA, the federal agency most intimately involved with oceanographic and coastal problems. NOAA could receive funds to support scientific efforts and provide some aid to critically evaluate research programs and their results.

It is clear that both Canada and the U.S. will have an interest in this project. U.S. and Canadian agencies and scientists should therefore collaborate on the planning and execution of the needed research. It is equally clear that the scientific results will reflect the expertise of individual scientists. Only the most highly qualified researchers should be approached to conduct the necessary work.

VI. TIME SCHEDULE



24-222 O - 83 - 12

Possible Impact of Large-Scale Tidal Power Developments in the Upper Bay of Fundy on Certain Migratory Fish Stocks of the Northwest Atlantic

by

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ABSTRACT

Dadswell, M.J., G.D. Melvin, P.J. Williams and Gail S. Brown. 1983
Possible impact of large-scale tidal power developments in the upper bay of Fundy on migratory fish stocks of the Northwest Atlantic.
Can. Tech. Rep. Fish. Aquat. Sci. 000.000-000

Megatidal embayments of the upper Bay of Fundy are occupied in summer by large numbers of feeding fish, particularly alosids. The American shad present contribute to a local fishery. Tagging experiments indicate these shad are drawn from all stocks native to rivers on the North American Atlantic Coast from Florida to Quebec and a large portion of the total western Atlantic adult shad stock, estimated at 3.5×10^7 individuals in 1981, may be present in the upper Bay of Fundy each summer. Construction of large-scale tidal power structures on these embayments will alter the habitat by changing turbidity and temaperature regimes and may alter migratory routes of the species concerned. Additionally repeated passage through the turbines may cause significant mortality.

Key Words: megatidal, alosids, American shad, migration, populations, low-head turbines, turbine mutilation rates, impact velocities, Minas Basin, Cumberland Basin.

Recent research conducted in the megatidal embayments of the inner Bay of Fundy (Cobequid, Cumberland, Shepody) indicates these regions are occupied in summer by an assemblage of migratory fishes numerically dominated by alosids (Dadswell et al. 1983a). The assemblage consists of alewife (Alosa pseudoharengus), blueback herring (A. aestivalis), American shad (A. sapidissima), Atlantic salmon (Salmo salar), striped bass (Morone saxatilis), Atlantic sturgeon (Acipenser oxyrhynchus) and dogfish (Squalus acanthias). Of these, shad were selected for concentrated study because of their apparent abundance in the region, moderately large size, ease of capture in large numbers and a thriving commercial and sports fishery here and along the Atlantic Coast. We believe, however, our remarks apply equally to other species of fish which occur in and/or utilize the embayments in a manner similar to shad.

The American shad, Alosa sapidissima (Wilson, 1811), is a large, anadromous clupeid, 40-50 cm in length and 1-2 kg in weight at maturity, which ranges from Florida to Labrador. Shad are migratory, moving north to south and back again annually, following an ocean isotherm envelope of 7-17°C (Leggett and Whitney 1972) and homing to their natal rivers for reproduction (Dodson and Leggett 1973). Commercial fisheries are usually concentrated in or near estuaries of rivers and exploit mature shad returning to spawn during a short spring season (Walburg and Nichols 1967). Sport fisheries occur in the upper reaches of rivers, the largest, by number caught and anglers participating, are on the Delaware and Connecticut rivers (annual sport catch - 20,000-100,000 shad)(Miller et al. 1982; Leggett 1976). The commercial fishery of the inner Bay of Fundy is concentrated in Minas Basin and Chignecto Bay and is unique since it exploits non-spawning, ocean-feeding shad during an extended 4-month season, from June to September (Dadswell et al. 1983b).

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Between 1870 and 1900, annual shad landings for the inner Bay of Fundy averaged 2-4 x 10^5 kg/yr (Fig. 1), and constituted two-thirds of total Canadian shad landings. It was the most valuable fishery in the Bay of Fundy at the time (Dadswell et al. 1983b). North American landings during this period peaked at 3.0 x 10^7 kg, about one-third from the Delaware River Basin (Fig. 2). After 1900, landings declined drastically as a result of markedly decreased shad abundance (Leim 1924). Reasons for the decline were damming of natal rivers [dams blocked 2/3 of formerly available spawning habitat by 1930 (Walburg and Nichols 1967)]; pollution [0 ppm O_2 levels on Delaware River, May to October (Miller et al. 1982)]; climatic variation; and overexploitation. Since the 1950's, large-scale anadromous fish restoration programs, in many cases specifically for shad, have been in progress in the United States and shad abundance is increasing (Miller et al. 1982). Although Bay of Fundy fishermen agree that shad abundance has increased during the last decade and catch rate has increased fivefold (Fig. 3), total shad landings from the upper Bay of Fundy do not reflect this fact because of poor local markets and therefore minimal fishing effort. The 1980 commercial landings and value for shad in Canada and the United States were 2 x 10^5 kg and $US171,000 and 1 x 10^6 kg and $US 2 million, respectively. Female shad landed between Florida and Virginia, during January through March, are worth up to $US3.85/kg to the fishermen. The value of the sport fishery on the Delaware and Connecticut rivers is estimated at $US10 million/yr (Miller et al. 1982; Leggett 1976).

Our research indicates shad arrive in the Bay of Fundy from the south during late May and migrate around the Bay in a counterclockwise direction using the residual current system for migratory assistance (Fig. 4; Dadswell et al. 1983b). The runs peak in the inner embayments during late June

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through July, lasting about 12 weeks or until mid-August in Minas Basin (Fig 5) and about 16 weeks or until mid-September in Chignecto Bay (Fig. 6). Shad are abundant within the embayments because the run effectively doubles back on itself. The increased turbidity levels in these regions apparently cause the shad to swim high in the water column and reduces gear avoidance, resulting in a high catch per unti effort for the local commercial fishery (Dadswell et all 1983b).

During 1979 to 1982, 14,500 shad were tagged and released in Minas and Cumberland basins and in the Annapolis River. Tag returns for ocean-tagged shad (Minas, Cumberland) were 22(7%) from Canadian marine locations, 60(21%) from coastal U.S.A. waters, 21(6%) from Canadian rivers, and 177(66%) from U.S. rivers (Fig. 7). Tag returns of Annapolis shad were 35 from the Annapolis River in the next year after tagging, 12 from Canadian marine locations and 5 from coastal U.S.A. waters. None were taken in U.S. rivers. Recaptures within the Bay of Fundy indicated the average migration rate of shad while in the Bay is 3.7 ± 0.94 km/day relative to the shoreline (Table 1). Realizing that shad return to their natal rivers to spawn (Walburg and Nichols 1967) as the Annapolis River shad demonstrated, the distant recapture from many rivers of those tagged in the upper Bay of Fundy during summer reflecting their intermixed population structure (Dadswell et al. 1983).

Within the megatidal embayments mean time-at-large for shad recaptured by gillnet was 5.4 and 5.1 days in Cumberland and Cobequid, respectively (Table 1). Mean time-at-large for those recaptured in weirs at the outlet of Cobequid Bay was 18.9 days (Table 2). During 1982 shad were batch tagged over a three-day period each week and analysis of gillnet recaptures (commercial and experimental) revealed 78% of recaptures were made within 1-3 days or a 2- or 3-week period occurred (12-29 days) before there was a

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second set of recaptures (Fig. 8). The difference was significant ($F_{7,30} = 7.97$; $P = 99.9$). Time-at-large before recapture in weirs represented a similar ratio in reverse (75% at large more than two weeks, Fig. 8) but the period of recapture of a batch of tags extended for a longer time (e.g. 8 days for shad tagged on June 16 (Table 2)), possibly because the weirs were longer than gillnet sets (1500 m vs. 500 m) and there were two, 3000 m apart.

These data suggest we tagged spatially discrete groups of shad dependent upon the actual area of water which was fished. During 1982, 80% of our fishing took place in the water mass occupying the head of Cobequid Bay at high tide (Fig. 9). Tag returns indicate shad followed an orderly progression through this region (Table 2), possibly in a pattern similar to Figure 9, and each shad or discrete group of shad occupied it at high water during a single 1-3 day period. Since it then took 20-30 days for a shad to progress from the head of Cobequid Bay to Economy Point while leaving the Bay (Table 2), it is reasonable to assume that it takes them a similar period to reach the head. Therefore the total residence time for an individual shad or group of shad in Cobequid Bay might be 40-60 days and, by the same reasoning, residence time in Cumberland Basin appears to be 10-15 days.

We used a modified Peterson model to estimate the number of adult shad occurring in the water mass at the head of Cobequid Bay during high tide for any 3-day period between June 15 and 30, 1982. Shad were recaptured for tagging with gillnets and recaptures were taken from weirs inside Economy Point (Fig. 9). Estimates were adjusted for tags applied in other parts of Cobequid Bay during this period and recaptures indicated that only fish present at the head of the Bay between June 15-30 were in the vicinity of the weirs when high catch rate conditions prevailed in mid-July (Table 2, Fig. 10).

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Based on these assumptions, the mean 3-day estimate was 6.9×10^4 shad (Table 3). Since our tagging data indicate the summer shad population of Cobequid Bay is transient, with some arriving inside Economy Point for the first time, some reaching the head, and some leaving the Bay on each tide cycle, we believe the 3-day estimate represents the mean size of a discrete group of shad occupying the head of the Bay for about 2.2 days or 4 tide cycles. It leaves the area after this period, and is replaced by a new group and so on. Thus, on any one day in summer the total adult shad population of Cobequid Bay would be the sum of all these groups or:

$$\text{Mean 3-day } \frac{\text{estimate} \times \text{total tides during residence } (\bar{x} = 50 \text{ days})}{\text{Number of tides at head of Bay}}$$

$$= 6.9 \times 10^4 \times \frac{100}{4} = 1.7 \times 10^6 \text{ adult shad}$$

Similarly the total number of adult shad migrating through Cobequid Bay in 1982 can be estimated where

$$\text{Mean 3-day } \frac{\text{estimate} \times \text{total tides during run (12 weeks)}}{4}$$

$$= 6.9 \times 10^4 \times \frac{168}{4} = 2.9 \times 10^6 \text{ adult shad}$$

Tag returns to date indicate each large embayment (Minas, Chignecto) has a separate group of shad during a given summer and embayment selection by any group may be random (Fig. 4; Dadswell, unpublished data). If Chignecto Bay contains a number of shad similar to Minas Basin each summer, and gillnet catch/effort data suggest this is true (Dadswell et al. 1983b), then the upper Bay of Fundy would contain about 6 million adult shad each year. This represents about 1/4-1/3 of the estimated 1981 western Atlantic adult shad stock (Table 4).

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Again, as our tagging data suggest, if shad follow a set migration route, in and out of Cobequid Bay with each tidal excursion (Fig. 9), advancing at a rate of 3.5 km/day, remaining in the region for about 50 days, and taking a week to pass a given site, an individual might pass Economy Point up to 30 times while entering and leaving Cobequid Bay. This may mean, even under a reduced tidal range after barrage installation, an individual shad could pass through the barrage, and hence the turbines, 10-20 times or more depending on the mode of operation. Similarly shad follow the tidal excursion while advancing through Cumberland Basin and there a shad might pass the Peck Point site 5 or more times under reduced tidal regimes. Using the mathematical relationships developed by Von Raben (1957), the water lengths (i.e., distance between each pass of the runner blades), impact velocities (velocity of fish striking blade), and mutilation rates (% by fish length) were calculated for the specifications of the proposed STRAFLO turbines at Economy Point (B9) and the Annapolis River (Table 5). Although the revolutions/minute of a STRAFLO turbine are low compared to other hydroelectric turbines, its large diameter means the blades are actually turning at high speed (up to 27.5 m/sec tip velocity) and impact velocities are similar to or greater than Kaplan or Francis turbines. On the other hand, calculated mutilation rates are low when compared to the latter turbine types, especially for smaller fishes (<30 cm). At Annapolis the STRAFLO turbine will probably pose little hazard for small- and medium-sized fish (Table 5), since most will pass the turbine only once/year during downstream migration. Large fish, like striped bass and Atlantic sturgeon, however, which remain in or near the estuary for their life or are so large the probability of a runner strike on each pass is high (over 30%), may suffer. In Cobequid Bay and Cumberland Basin, where the fish are moving in and out with the tide making repeated passes through the turbine, mutilation rates will be higher and can be calculated using the exponential survival relationship (i.e., fish

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not mutilated) where:

$$N_0(1 - \text{mutilation rate})^{\text{passes}} = \text{Survivals}$$

A population of 100,000, 50-cm shad after 5 passes would have $100{,}000(1-0.095)^5 = 60{,}700$ survivors or 39,300 mutilated. After 10 and 20 passes, 63,200 and 86,500 will have been hit. In other words, 40, 70, or almost 90% will have been struck. Since most experimental work with turbines indicates the Von Raben relationship overestimates mutilation rates by a factor of 2 (Ruggles 1980), the calculated rates can be adjusted downward to a range of 20-45%. If most of these mutilations result in mortality, and this relationship is unknown, then large-scale structures with an array of turbines may impose an unacceptably high mortality rate on the presently recovering western North Atlantic shad stock.

There remains a number of questions to answer before the limits of this problem are resolved. Data on actual mutilation rates experienced at the Annapolis STRAFLO turbine will allow more accurate modelling of the Economy Point (89) project. Sonic tagging and tracking of fish will help clarify their behaviour around the Annapolis turbine and determine the validity of our hypothesis concerning fish movement in Cobequid Bay and Cumberland Basin. The resource inventory of these embayments is incomplete, as is our knowledge of their contribution in the life history of the Atlantic Coast migratory stocks of alewife, blueback herring, Atlantic sturgeon, striped bass and dogfish. Finally, we should determine how returning adult Atlantic salmon behave during their residency in these embayments before they enter the local rivers to spawn. Our few tag returns for this species indicate an individual salmon may remain at sea in this area for up to a month (Table 2). If they follow the tidal excursion similar to the shad, there exists the possibility of high turbine mortality, which might place the salmon runs in the Shubenacadie, Stewiacke, Salmon, Portapique, Economy, Maccan, Hebert, Petitcodiac and Shepody rivers in

jeopardy.

Acknowledgments

We wish to thank Jim Martin, Carl Jarvis, Mike Kellock, Stephen Bubine, Daphne Themelis, Judy Dawson, Roger Rulifson, and his students from Unity College, Leslie Linkletter, Brenda Blanchard, Peggy Crawford and Madelyn Irwin for their assistance in the field and in assembling this report. Shad fishermen, Marven Snowden and Russel Cooke helped in many technical matters related to gillnet drift fishing. Art Lupin of New Jersey Fish and Game, Peter Minta of Connecticut Department of Environmental Protection, and Bob Krska of the University of Massachusetts kindly provided unpublished data on the estimated and observed populations in the Delaware and Connecticut rivers. Madelyn Irwin typed the manuscript and Frank Cunningham prepared the figures.

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Table 1. Recaptures during same year in the Bay of Fundy/Gulf of Maine for shad tagged in Annapolis River, Cumberland Basin and Minas Basin.

Place Tagged	Place Recaptured	Mean Time at Large n	(Days)	Minimum Migration Distance (km)	Migration Rate (km/day)
Annapolis	Cobequid	6	57.0	220	3.9
Annapolis	Cumberland	5	64.1	160	2.5
Annapolis	Shepody	3	49.6	210	4.2
Annapolis	Saint John	1	71.0	360	5.1
Annapolis	Head Harbour	5	102.3	440	4.3
Annapolis	Grand Manan	3	132.0	470	3.6
Cobequid	Cobequid (Gillnet)	9	5.1	15	2.9
Cobequid	Cobequid (weir)	16	18.7	40	2.1
Cobequid	Head Harbour	1	99.0	250	2.5
Cobequid	Gulf of Maine	4	118.0	625	5.3
Cumberland	Cumberland	33	5.4	30	5.5
Cumberland	Shepody	12	13.9	50	3.6
Cumberland	Gulf of Maine	1	131.0	310	2.4

$\bar{X}$ = 3.7 km/day

Table 2. Recaptures of tagged adult shad by weir and gillnet in Cobequid Bay, Nova Scotia, during 1982.

Weir			Gillnet		
Date Tagged	Date Recaptured	Days at Large	Date Tagged	Date Recaptured	Days at Large
June 10	June 16	6	June 15	June 16	1
June 16	July 10	24	June 23	June 24	1
June 21	July 13	22	June 16	July 7	21
June 24	July 15	21	June 23	June 23	1
June 25	July 11	16 EW[1]	June 25	June 28	3
June 16	July 11	25 EW	July 5	July 8	3
June 16	July 11	25	July 1	July 14	13
June 16	July 15	29	July 7	July 8	1
June 16	July 11	25	July 21	July 23	2
June 22	July 16	24		Mean Days at Large	5.1
June 23	June 30	7			
June 29	June 30	1			
June 28	July 22	24 EW			
June 29	July 22	23 EW			
June 29	July 11	12 EW			
July 2	July 17	15			
	Mean Days at Large	18.7			

One Salmon

Tagged - July 14

Recap. - Aug. 10

27 Days

Table 3. Modified Peterson population estimates for adult shad occurring in the head of Cobequid Bay, Nova Scotia, during June 15-30, 1982. Number tagged adjusted for tags applied in other parts of Cobequid Bay which were unavailable to the weirs during the period (20%).

Shad Group Period	Number Tagged	Weir Recapture Period	Recaptures	Total Weir Catch	Population Estimate	3-Day Population
June 15-18	168	July 5-16	4	2982	10.1×10^4*[a]	10.1×10^4
June 21-24	164	July 10-21	3	1804	7.4×10^4*	7.4×10^4
June 16-23	268	July 6-23	6	3042	11.7×10^4**[b]	5.8×10^4
June 15-30	687	June 22-July 30	9	3187	22.0×10^4**	4.4×10^4
					Mean 3-Day Population	6.9×10^4

[a] Estimate not valid $MC \leq 4\hat{N}$

[b] Estimate valid $MC > 4\hat{N}$

Table 4. Population estimates of the Atlantic Ocean stock of adult American shad by simple Peterson method.

Tagged	Recaptured	M	C	R	$\hat{N}$	MC>4N
Cumberland 1980	Holyoke Connecticut R. 1981	2416	380,000	10	$9.1 \times 10^7 \pm 60\%$	>1* [1]
Cumberland 1981	Holyoke Connecticut R. 1982	3200	295,000	26	$3.6 \times 10^7 \pm$	>1*
Saint John Harbour 1981	Holyoke Connecticut R. 1982	280	295,000	4	$2.06 \times 10^7 \pm$	>1*
Cumberland 1981	Delaware R. 1982 Est. Population	3200	509,000	30	$5.4 \times 10^7 \pm$	>1*
Cumberland 1981	Delaware R. 1982 Sport Catch	3200	53,960	28	$0.6 \times 10^7 \pm$	>1*
Cumberland 1980	Delaware R. 1981 Est Population	2416	546,000	10	$13.2 \times 10^7 \pm$	>1*
Cumberland 1980	Delaware R. 1981 Sport Catch	2416	40,420	7	$1.4 \times 10^7 \pm$	>1*
Cumberland 1981	Annapolis R. 1982 Est Population	3200	100,000	5	$6.4 \times 10^7 \pm$	>1*

[1] Estimate valid

Table 5. Water length and impact velocities of STRAFLO turbines from specifications given by the Fundy Tidal Power Board and related estimated potential fish mutilation rates.

Site	Rev/Min	Water Length (m)	Impact Velocity (m/sec)	Mutilation Rate (% by length)
Minas 09	70	2.26[1]	23.99[2,3]	30 cm - 5.7%[4] (alewife)
Discharge = 378 m^3/sec; Blades = 4; Diameter = 7.6 m; Hub = 2 m(est.); α = 32° — For both turbines				50 cm - 9.5% (shad)
				80 cm -15.2% (salmon)
				100 cm -19% (bass,dogfish)
				200 cm -38% (sturgeon)
Annapolis	50	3.17	16.87	50 cm - 6.8% (shad)

[1] $\text{Water Length} = \dfrac{240 \times \text{Discharge } m^3/\text{sec}}{\cos\alpha \cdot \#\text{ Blades} \cdot \text{Rev/Min} \left[\text{Runner diameter}^2(m) - \text{Hub diameter}^2(m)\right]}$

[2] Impact velocity calculated from Von Raben 1957

[3] Critical borderline mutilation velocity between 11-14 m/sec (Von Raben 1957)

[4] $\text{Mutilation rate} = \dfrac{\text{Fish length (cm)} \times \text{mutilation ratio}(^{\text{theoretical}}/_{\text{observed}})}{\text{Water length (m)}}$ (Von Raben 1957)

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Transnational Legal Issues and Fundy Tidal Power

by

Robert W. Rudolph and Peter F. Larsen

Key Words: Tidal power, Gulf of Maine, Bay of Fundy, Minas Basin, International Law, Tidal Change, Transnational pollution, Environmental Consequences

From: O. Magoon (ed.) Coastal Zone '83: Proc. 3rd Symp. Coastal and Ocean Manag. A,. Soc. Civil Eng. 12pp. San Diego, Calif.

TRANSNATIONAL LEGAL ISSUES AND FUNDY TIDAL POWER

Robert W. Rudolph[1] and Peter F. Larsen[2]

Abstract

Interest in the potential of tidal power is at an all-time high. The French LaRance project has been operating successully since 1967 and several other projects are being studied in France and Britain. Interest in North America centers on the Gulf of Maine where the demonstration project at Annapolis Royal, N.S. will be completed in June 1983. The 4,000 MW project proposed for Minas Basin is unique because of its size and its capacity to modify the tidal regime in the Gulf of Maine. The modified tidal regime will have complex, far-reaching environmental consequences, both positive and negative, which will be felt on the U.S. side of the border. A framework is needed to address the legal implications of these environmental consequences and to insure that the best interests of all the people of the region are served. The authors suggest that the existing International Joint Commission may be a viable mechanism for accomplishment of these goals.

Introduction

The generation of electricity by turbines turned by tidal water is a concept that may be coming of age. Centuries ago coastal mills were commonly driven by tidal energy and the practice was only discontinued with the advent of engines and inexpensive fossil fuels. However, rising energy costs resulting from increased fossil fuel costs, along with concern about the safety of nuclear power, has sparked a renewed interest in developing tidal power resources. Tidal energy has several advantages over conventional energy sources. It is a renewable source of energy that is not influenced by seasonal water levels, floods, or droughts as is conventional hydropower. Although most operational modes only produce power on an intermittent basis requiring tidal power facilities to be integrated with other systems, power production is predictable years in advance. Since it uses no fuel, problems associated with fuel acquisition and waste product disposal are avoided.

Although interest in the potential for tidal power has been manifested periodically, there has never been such a high degree of activity as there is today. The 240 MW LaRance project on France's Brittany coast has been operating successfully since 1967. Other sites are presently being evaluated along the coasts of Brittany and Normandy. The British are continuing their consideration of the Severn Estuary

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barrage and have already completed extensive environmental studies. In North America, interest in the potential of tidal power is high in the Gulf of Maine-Bay of Fundy region (Fig. 1). There are at least three projects being studied on the United States side of the border. The Passamaquoddy Indian Tribe has done extensive studies on the potential for a 12 MW tidal unit on their reservation in Perry, Maine. Also in Cobscook Bay, the U.S. Army Corps of Engineers is evaluating several possible tidal dam configurations and operating modes. A very small, private initiative is underway in central Maine and, if construction begins in 1983 as planned, this could result in the first active tidal power plant in the U.S. In addition, the State of Maine is surveying its shoreline to establish its cumulative tidal power potential.

The vast majority of North American interest in tidal power during the last decade has been focused on the upper Bay of Fundy. The first tidal power plant in the western hemisphere will go on line at Annapolis Royal, Nova Scotia in June 1983. This project consists of a 20 MW low head Straflo turbine fitted into a pre-existing barrage. Its purpose is to demonstrate the utility of the turbine in the marine environment. Construction costs using this type of turbine are 10-15% less than those associated with more conventional low head turbines, so the success of this pilot project could have a significant impact on the feasibility of large scale developments. Several sites for large scale tidal power developments have been studied in the upper Bay of Fundy. For the last two years extensive and intensive technical, economic and environmental consideration has been directed at one site, designated B9, in the Minas Basin (Fig. 1). This site is now considered the most likely for large scale

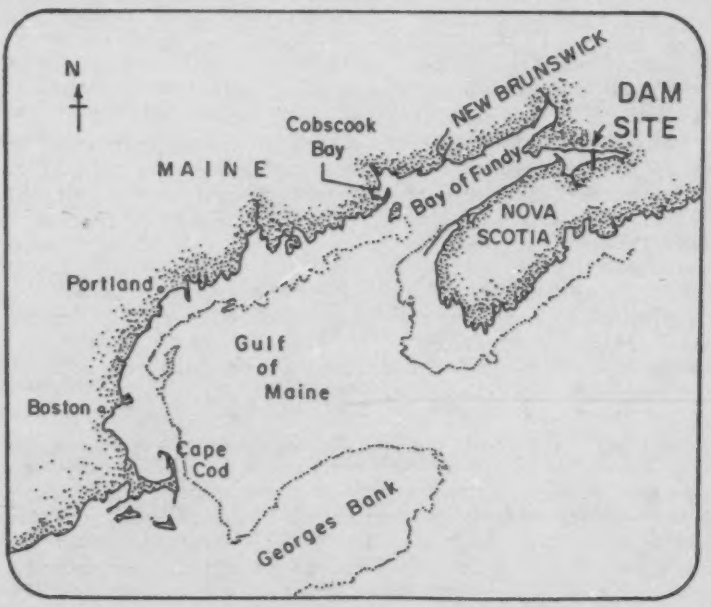

Fig. 1. The Gulf of Maine-Bay of Fundy region.

tidal power development and its construction is being advocated by both private and governmental concerns in Nova Scotia.

The Minas Basin project is expected to be one of the largest of its type in the world. The north-south running barrier will stretch approximately five miles across the Minas Basin between Economy Point and Cape Tenny in Nova Scotia. The optimum scale of the single-effect tidal generating station calls for 106 turbines, with a total capacity of 4028 MW, and 60 sluices. Although design plans are not definite at this time, this appears to be the preferred design and the one on which all calculations have been based. Other designs project a capacity of up to 6,000 MW. This project would provide energy for regional power needs, including both the Maritimes and those of the northeastern United States. In 1981, the Tidal Power Review Board, a Nova Scotian based body consisting of both provincial and federal representatives authorized an update of a 1977 study entitled "Reassessment of Fundy Tidal Power." The recently released update showed that in the intervening period, significant changes had occurred enhancing the economic feasibility of tidal power.

The benefits of a tidal plant at the Minas Basin site due to fuel cost savings would far surpass capital and operating costs for an arbitrary, but reasonable allocation of 10% to the Maritimes, 45% to New England, and 45% to New York. Depending on construction method, the benefits would be between 2.5 to 3.0 times the costs. When compared on a preliminary basis to alternate energy sources, the benefits to the marked areas for tidal were found similar to nuclear and superior to coal (3). Despite the anticipated $22 billion in costs for the project during its twelve-year construction period, it is expected that Fundy tidal power could earn billions of dollars a year for the Maritime producers.

Transnational Environmental Consequences

The proposed Minas Basin project is not only unique because of its size. It is also unique because some, perhaps the major, environmental impacts will occur in another country, i.e. the United States. Extensive numerical modelling has lead to the conclusion that the proposed Fundy tidal power development will enhance the natural tidal resonance of the Bay of Fundy and Gulf of Maine by shortening the basin, bringing its period closer to the natural period of the tidal wave and hence increasing the tidal amplitude in the Gulf of Maine. Present estimates indicate that an increase in tidal range of approximately thirty cm. would be produced from the southern Bay of Fundy to Cape Cod, Massachusetts (Fig. 2) (5).

Altering the tidal regime of the northern Gulf of Maine will produce a multitude of environmental consequences diverse in scope and ranging widely in time-scale of development. Although the work of Greenberg and others have produced sophisticated numerical models of modifications in tidal behavior induced by tidal power development in the upper Bay of Fundy, little attention has been given to consideration of the resultant environmental consequences. Recognizing that these changes might have a significant impact on the coast of Maine and its inhabitants, the Maine State Planning Office has funded

a six month preliminary study through the Bigelow Laboratory for Ocean Sciences to determine what environmental and socio-economic consequences would most likely be felt in Maine. It is assumed that New Hampshire and most of the Massachusetts coast would experience similar effects.

The environmental consequences of tidal power development seaward of the tidal barriers can be divided into those caused principally by changes in tidal range and those caused by changes in tidal currents. Although both are manifestations of the same phenomenon, tidal range effects will be most pronounced at the coastline, while tidal current effects will be felt over a wider area. It should be noted that sea level remains unchanged.

The predicted increase in tidal range will cause alterations in the extreme upper and lower portions of the intertidal zone, that productive region of shoreline which is alternately covered and exposed by the sea. Even modest changes in tidal range will mean that points near the present tidal extremes will be submerged or exposed on a more frequent basis. This will lead to a restructuring

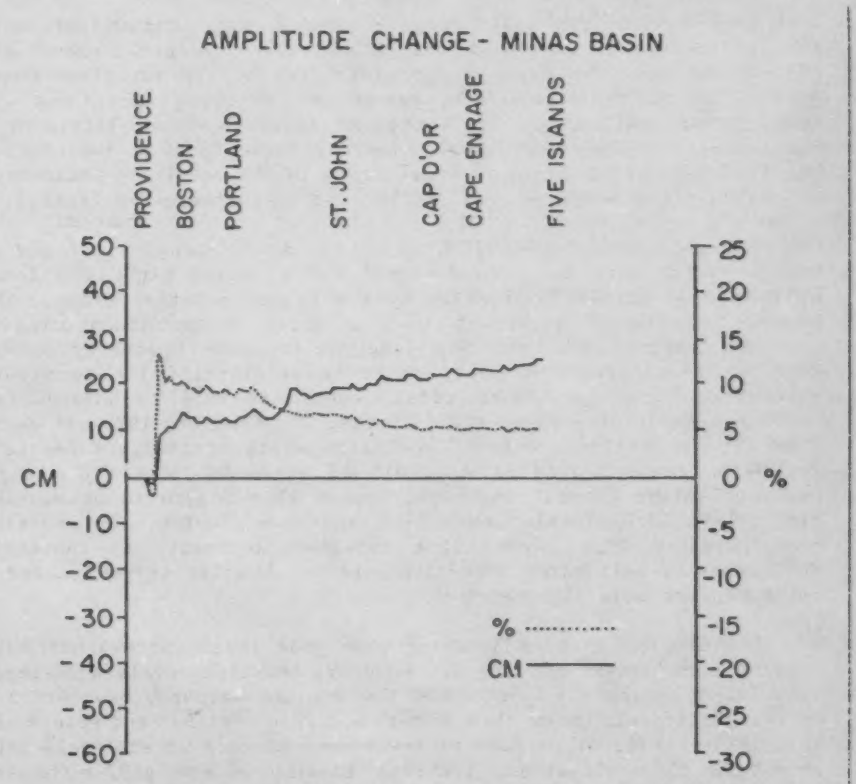

Fig. 2. The absolute and percentage change in tidal range along the Gulf of Maine coast. Tidal range is twice the amplitude change.

of the resident biological communities near high and low water. These communities are finely tuned to, and limited by, the rhythmic pattern of immersion and submersion. The best example is perhaps the salt marshes which can be large in extent and which exhibit marked zonation of community types over a limited vertical gradient, i.e. large horizontal distances are associated with small elevation changes. The zonation is caused principally by the dominant plant's tolerance to submersion - plants tolerant to frequent submersion living at lower tidal heights and less tolerant plants dominating at higher tidal heights with intolerant plants completely excluded from the tidal zone. The projected increases in tidal range will increase the frequency of inundation and, over an undefined period of time, result in an upward, i.e. shoreward, movement of plants of the intertidal zone. The higher water levels at mean high tide will reach elevations not previously inundated and marsh plants will displace terrestrial vegetation. In effect, marsh area will be increased along landward borders. Analogous effects will occur in all intertidal habitat types and also at the lower end of the tidal range where more hardy intertidal species will replace specialized subtidal forms in the expanded lower intertidal zone.

Expansion of the tidal range could also have significant implications for the human population. Higher tides, as noted previously, will cause the loss of terrestrial habitat at the immediate shoreline. The absolute loss will depend on the type, slope and wave exposure of the shore. The increased tides may have little or no consequence on steep rocky shores such as those found on the northern coast of Maine, but could be significant in the low-lying sedimentary shores that characterize most of the rest of northern New England.

Man-made structures, such as piers, docks, low-lying roads and bridges which have all been designed for existing high tide levels will be more closely approached by the higher modified tides. This becomes especially important when a storm surge accompanies an enhanced spring tide and may lead to increased property damage. Erosion of beachfront property could be accelerated if storm waves associated with the higher tidal levels are able to undercut sea walls designed for present tidal levels. The February 1978 nor'easter that hit New England caused $47 million worth of property damage in the Maine coastal area as a result of extremely high tides and a prolonged storm front. One might expect this figure to be somewhat greater should high tide levels be six inches greater. In addition, the increased tidal levels are expected to result in increasing incidences of salt water intrusion into fresh water wells located in the immediate coastal zone.

Conversely, a storm arriving when tide levels were lower might prevent some amount of damage. However, low-tide levels will impact some other areas. In many small New England harbors, navigation is already difficult near low water and many docks and piers are marginally useful at periods of low tide. Reduced water levels could aggravate this situation, reducing boating access and/or in some cases necessitating dredging or extending piers into deeper water.

Predictions of changes in tidal currents are more difficult to make and hence, projections of environmental consequences are on less firm footing than those based on tidal range changes. Yet, changes in tidal currents can have profound and far-reaching effects on the entire Gulf of Maine including Georges Bank. It has been predicted that a large Fundy power development could increase tidal currents in the Gulf of Maine by 5%.

In the nearshore environment, an increase in current strength will undoubtedly affect the dynamic equilibrium of sedimentary structures such as intertidal sand and mudflats, subtidal bars, shoals and channels. If these effects are large enough, intertidal clam and worm resources may be impacted and dredging may be needed to keep shipping channels open. Of course these environments will become restabilized in a period of time after a new equilibrium is established.

Increasing current strength will alter the flushing characteristics of northern New England estuaries and could have a pronounced effect on the seasonal temperature range, pollutant assimilation, nutrient supply and hence, productivity. Estuarine faunal communities may experience a reduction of larval retention within the estuaries.

Perhaps the most far-reaching consequence of tidal current modification is the potential change in mixing characteristics. Garrett and his colleagues predict a slight expansion in the well-mixed areas and a reduction in stratification elsewhere (4). The decreased stratification could result in an increased supply of nutrients to the surface waters and a 1°C decrease in summer surface water temperature with a corresponding decrease in air temperature. Ultimately, this could result in an increase in primary productivity of the Gulf of Maine. Whereas changes in primary productivity should be reflected in secondary productivity, it would be premature to comment on how specific fisheries might be affected. Undoubtedly, a decrease in temperature will benefit certain species, inhibit others, which directly or indirectly require some threshold temperature for feeding or reproduction, and have minimal or no effect on others.

Again, as with tidal range changes, these tidal current changes could have a significant impact on the human population. Changes in water temperatures and subsequent alterations to fisheries will affect that portion of the population which depends on the living marine resources of the Gulf of Maine. The increased currents may necessitate greater horsepower requirements as part of the fishing effort and ship handling on the whole will be made more difficult. Altered meteorological conditions could shorten the coastal growing season and affect the tourist industry should the incidence of fog days increase.

This is by no means a comprehensive list of the biological, physical and socio-economic consequences of tidal power development. Some consequences are apparently detrimental, while others are seemingly beneficial. They are complex, interrelated problems which need greater research efforts to provide a suitable data base for proper

decision making. The problems are compounded by the fact that the impacts are felt across an international boundary.

Some Legal Aspects of Fundy Tidal Power

Although politics, economics and energy needs in the northeast will play the major roles in determining whether or not tidal power development in the Bay of Fundy becomes a reality, one should consider the implications in international law should a project be built which results in these projected environmental modifications.

The field of international environmental law is constantly evolving. Political boundaries pose no barrier to pollution and as the products of global growth continue to cross the transboundary area, man has had to develop new legal regimes to deal with the growing problems facing our environment. Within this framework of evolution, we should reexamine our definition of "pollution." Traditional dictionary definitions no longer adequately describe the increasing stresses to which we subject our environment. This is especially true with respect to the marine environment. Because of the extremely wide range of harms and hazards envisaged, it has not been easy to define the concept of marine pollution (8).

When we consider the ecosystem changes which could result from the Fundy tidal project, we have to ask if these effects can be considered a form of pollution. There is some evidence to suggest that in evolving international law, they might be. A group of scientific experts working for the International Oceanographic Commission defines "pollution of the marine environment" as meaning the introduction by man, directly or indirectly, of substances or energy into the marine environment which results or is likely to result in such deleterious effects as harm to living and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of seawater and reduction of amenities (9). This definition may require even further expansion as activities such as extraction of some mineral resources (manganese nodules) imply no introduction of any type, but still may have significant environmental effects.

In 1972, the Stockholm Conference on the Human Environment established the foundation for the international responsibility of states with regard to the environment. "States have in accordance with the Charter of the United Nations and the principle of international law, the sovereign right to exploit their own environmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction" (9). Although only a set of recommendations binding on no nation, this principle has come to be regarded as customary law. Provisions in the controversial Law of the Sea Treaty, which the United States has yet to accept, reflect this principle and attempt to strengthen it with respect to the marine environment.

In the past decade of environmental awareness we have seen a number of international agreements and treaties adopted to deal with

the problems of transboundary pollution. On a worldwide basis, the largest majority of treaties in existence which deal with protection of the marine environment concern themselves with the problems of oil pollution and waste disposal. While there are a few agreements such as the Intergovernmental Maritime Consultative Organization's MARPOL Convention and the 1972 London Dumping Convention, which are designed to protect the global commons, most are designed to protect regional hydrographic basins. Perhaps the strongest existing environmental treaty is the Nordic Convention of the Scandinavian Countries which covers all types of environmental problems, including but not limited to problems relating to water, sand drift, air pollution and changes in temperature. This treaty offers the possibility for individuals who are affected or may be affected by a nuisance caused by environmentally harmful activities in another state to bring the question of permissibility of such activities to court in the offending state. Compensation is based on rules no less favorable than the rules of the offending state (1).

The United States and Canada have long recognized the responsibility to pay compensation as a result of transnational pollution injuries. In the precedent setting Trail Smelter Dispute, an international arbitration tribunal ruled that Canada was liable for damages occurring between 1925 and 1938 to farmlands in Washington State as a result of sulfur dioxide emissions from a smelter operation located 12 miles north of the border in British Columbia. Similarly, in 1972, the United States was held responsible for the fouling of beaches in British Columbia by the accidental release of 12,000 gallons of crude oil from a tanker unloading at a refinery in Washington.

Although the United States and Canada have a long history of cooperation in peacefully solving transboundary problems, it is these increasing environmental problems that may lead to strained relations in the future. Almost daily we find reports about the dangers of acid rain in our newspapers and, while there may still be some question as to where the problem originates, it is the general consensus that coal-fired plants in the mid-western United States are causing degradation to aquatic and terrestrial life in northeastern Canada and New England. An agreement exists between Canada and the United States to devote more resources to studying the situation, but there seems to be a major effort on the part of the U.S. to downplay the severity of the problem. What ultimate decision is made on the part of the United States to work on controlling this problem may directly affect the way in which Canada may choose to view the projected environmental modifications from Fundy tidal power.

It is argued that domestic legislation is lacking in several respects in protecting the transfrontier environment. United States environmental legislation, traditionally strong, appears to be facing a gradual weakening in the 1980's. The National Environmental Policy Act (NEPA) requires that an assessment process be made of all types of projects prior to initiation in order to determine just what the probable effects on the environment are. Executive Order 12114 of President Carter in 1979 was designed to further the purpose of NEPA abroad, but appears to be based on the premise that environmental

review interferes with foreign nations' internal affairs. In reality, quite the opposite may be true. Calling for studies of major federal actions having input on foreign countries, the wording in this piece of legislation seems to undermine the general international principle of responsibility in protecting the environment abroad. It states that "...if the action also has effects on the environment of a foreign nation (aside from domestic effects), an environmental impact statement need not be prepared with respect to the effects on the environment of the foreign nation" (2).

Canadian environmental legislation, patterned after NEPA, lacks the strength of United States legislation and is often overshadowed by provincial legislation. One critic of Canadian environmental legislation remarks that "existing environmental impact policies are wholly dependent upon discretionary administrative and executive decisions of the respective cabinets, which often result in an over emphasis on political realities (particularly energy related decisions)" (10).

The above should not be interpreted as a condemnation of either United States or Canadian environmental legislation but should serve merely as an indication that there appears to exist certain gaps on a domestic basis which need strengthening to see that the global environment is protected.

In looking at the levels of government that might be prepared to deal with the Fundy situation it was discovered that a group known as the International Joint Commission (IJC) has successfully worked on a large number of projects with transboundary environmental implications since early in this century. In absence of a special treaty designed to consider a liability regime for environmental modifications resulting from Fundy tidal power development, it is our contention that this quasi-judicial body is the proper forum for studying the problem and deciding what should be done.

The International Joint Commission is a body of six members, three from the United States and three from Canada, with 28 binational advisory boards of engineers, scientists and other experts to conduct technical studies and field work as deemed necessary. The Commissioners conduct their business as a single body and not as separate national delegations representing their respective governments. The IJC was established as part of the Boundary Waters Treaty of 1909 to provide the vehicle, principles and procedures needed to promptly and equitably resolve disputes involving the boundary and transboundary waters. The Commission has three principle functions which circumvent the normal prolonged bilateral negotiations of diplomacy. First, it acts as a regulatory agency, approving or disapproving applications from government, companies or individuals for obstructions, uses or diversions of water which affect the natural level or flow of the boundary water on the other side of the international boundary. Secondly, it investigates questions or matters of difference along the common frontier and reports the facts and circumstances to each government and recommends appropriate action by them. A third function is to monitor compliance with the terms and conditions set forth in Orders of Approval that the Commis-

sion has issued and which have been accepted by the two governments (7). It is truly remarkable that in nearly 3/4 of a century of examining transboundary problems, the Commissioners have divided on national lines or failed to reach agreement in only three of more than 100 cases.

A fourth and powerful function of the International Joint Commission has never been utilized. It is one that permits the governments to refer any issues to the Commission for binding decision rather than only for a report and recommendations.

While the Commission has been chiefly concerned with the use of the common water resources shared by Canada and the United States, the problems of air pollution and now acid rain have been examined on a cursory level. Indeed there is no reason to think that the drafters of the Boundary Waters Treaty intended for the Commission to concern itself only with the common water resources. Article IX provides, in part: "The High Contracting Parties further agree that any other questions or matters of difference arising between them involving the rights, obligations, or interests of either in relation to the inhabitants of the other....shall be referred from time to time to the International Joint Commission for examination and report" (6).

Given the proven track record of the IJC in dealing with transboundary environmental issues, especially those involving uses of shared water resources, it would appear appropriate that the Commission should become the primary forum for referral and approval or disapproval of the Fundy tidal project. It may be only through a body such as the IJC that politics and economics can be pushed aside in favor of an environmentally sound decision. The Commission believes this is their role. Both Canada and the United States will increasingly be confronted by the dilemma of what will appear conflicting choices - protecting the environment or protecting the economy. The IJC believes the temptation to choose economic gains at the expense of a healthy environment should be resisted in both countries (7)

Conclusions

This paper has been based on a myriad of assumptions, some visible and others not so obvious. Perhaps many of these assumptions may be viewed as being premature, but consideration of these issues which by no means is all inclusive, are important before plans continue to develop Fundy tidal power.

First and foremost, the assumptions that the project will be built and will lead to environmental modifications seaward of the barrage must be questioned in light of several awesome scientific, economic and legal uncertainties:

1) How accurate is the Greenberg model and does it adequately consider the effect of the open boundary? Have all of the anticipated modifications been considered? What is the likelihood of using

a different engineering design to minimize environmental consequences seaward of the barrage?

2) Will future energy demands in the region warrant the construction of a multi-billion dollar tidal dam in the Bay of Fundy given the fact that surplus Canadian hydropower is now available from Quebec and Ontario?

3) Can Canada raise the capital herself to construct such a project and/or to what extent will monies from the United States be needed to insure construction? What is the likelihood of U.S. involvement in Fundy tidal power if there is indeed a risk of environmental damage to the New England coastline?

4) What are the real benefits and total costs of tidal power development in the Bay of Fundy?

5) What does the future hold for environmental law on a domestic and international basis and will current global economic problems force environmental standards to be relaxed?

Perhaps there are more questions than answers when we begin to deal with tidal power on such a scale. It is not a new technology, having been around for centuries, but never before has man seriously anticipated exploiting it to this degree. Do we have the right to consider a project with such far-reaching, and largely uncertain, environmental consequences? The final realization must be that we live on one planet and we share a common responsibility to protect it.

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TESTIMONY OF BARRY S. TIMSON BEFORE THE UNITED STATES SENATE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS ON THE POSSIBLE EFFECTS OF CANADIAN TIDAL POWER DEVELOPMENT ON GULF OF MAINE BEACHES AND NAVIGATION, JULY 25, 1983

My name is Barry S. Timson. I am a resident of 9 Greenville Street, Hallowell, Maine. I am a consulting geologist and President of The Mahoosuc Corporation of 114 State Street, Augusta, Maine. I authored a portion of the State of Maine funded study, "A Preliminary Evaluation of the Environmental Consequences of Fundy Tidal Power Development to the Resources of the State of Maine". I have been asked by the United States Senate Committee on Environment and Public Works to testify on the possible effects of the tidal power projects in Canada on beaches and navigation along the New England coast.

TIDAL PROJECT EFFECTS ON COASTAL STORM SURGE LEVELS

Coastal storms, termed "Nor' easters" throughout New England, strongly influence the stability of New England's unconsolidated shorelines and the delivery of sediment from the coastal nearshore and shallow offshore to semi-enclosed lagoons, coastal ponds, estuaries and embayments. Over the past twenty years, geologic studies have documented that coastal storms are the primary cause of foredune retreat on beaches and barriers rimming the margin of the Gulf of Maine and a principal geologic agent for delivering suspended sediment from the nearshore floor of the Gulf of Maine to embayments where deposition occurs.

The Canadian tidal power projects will increase our semi-diurnal tidal amplitude by about 15 cm. according to the Greenburg Model. This will also lead to an increase of 15 cm. in coastal storm surge levels, as almost all of the storms passing through the Gulf of Maine require 12 hours or more to do so. This increase in surge levels of 15 cm. will, in effect, increase the number of damaging storms which impact the coast by a factor of 2.5.

I wish to make it clear that the projects will not influence our climate regimes and, thereby increase the number of storms which will impact our shores; but will increase the storm surge levels which would otherwise be experienced.

For example, Stone and Webster Engineering Co. (1978) determined that a coastal surge level of exceedance probablility 13.3% historically caused unexpected beach erosion and damage to man-made coastal structures. Storms of higher (greater than 13.3%) probability caused insignificant erosion or damage; those of lower exceedance probability caused even more significant erosion or damage. If 15 cm. of tidal amplitude are added to historical coastal storm surge levels, a coastal storm of 45% exceedance probability will become the threshhold storm which creates significant beach erosion and coastal damage.

From 1940 to 1979, the Gulf of Maine experienced only 11 storms of 13.3% exceedance probability and 30 storms of 45% exceedance probability. If the tidal power projects had been completed in 1940, Maine, New Hampshire and Massachusetts would have been impacted by 30 storms causing significant damage rather than 11.

In addition, the magnitude of storm damage expectancy will increase. With an increase of tidal amplitude of 15 cm., a 100-year storm of today will cause storm surge levels equivalent to a 300-year storm; a 50-year storm will be equivalent to a 200-year storm and a 25-year storm will be equivalent to a 100-year storm. All of us in New England are familiar with the February, 1978 northeast storm and the damage it caused. This storm is taken by most as the storm of record and the 100-year storm. From 1940 to 1979, only one storm of this magnitude occurred. If the tidal power projects had been completed prior to 1940, 3 storms of this magnitude or greater would have occurred.

These effects on coastal storm surges will be significant. It certainly warrants our attention as it translates into significant beach erosion, millions of dollars of damage to man-made coastal structures and facilities, and probable increased depostion of sand and mud in harbors and some navigation channels.

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IMPACTS ON COASTAL BEACHES

Our coastal beaches are in dynamic equilibrium with their environment. Sea-level rise, coastal storms, tidal processes, wind and wave processes, and sediment supply are the principal natural variables which control their position and behaviour.

Geologists seem to be split into two camps as to whether beach recession rates are caused mostly by coastal storm wave erosion or sea level rise. I am of that camp that believes that coastal storms are the major controlling variable, not sea level rise. Bruce Nelson, a rather talented former graduate student, found (1979) that the major beaches of Maine recede at a higher rate than can be explained by sea level rise. Sea level rise rates in Maine can account for 9 to 12 cm. of annual beach recession, but many beaches are receeding at a rate of about 30 cm. per year. Nelson, as well as myself, would attribute this to coastal storm erosion. I do not believe that an increased tidal amplitude, alone, will cause any more erosion on New England coastal beaches than is otherwise being experienced.

Increased recession rates will be experienced, however, mostly because increased storm surge levels will allow wave energy to be expended higher on the beach profile, allowing for deeper penetration of erosion. If we are correct in our assumption that coastal storms are the major variable control-

ling beach recession and the relationship between the amount of beach recession and coastal storm energy is linear, then the amount of recession which will be experienced by our major beaches because of the tidal power projects will be about 60 cm. per year. This relationship is probably too simple to be reality, but we are looking at a situation where recession rates will increase dramatically - from 1.5 to 2.5 times their present rates. The recession rates may even be higher, as recent investigations by the Maine Geological Survey hint that sea-level rise rates may be increasing along certain areas of the Maine coast(MGS, 1983).

PROJECT IMPACTS ON COASTAL NAVIGATION

It is now fairly well known that much of the sediment that is deposited in our shallow estuaries, lagoons and coastal embayments is derived from the ocean, especially in New England. Detmar Schnitker (1974) has nicely documented how important coastal storms are in eroding near- and offshore bottom sediments and transporting elevated concentrations of suspended sediment into coastal embayments. Much of the mud making up our tidal flats is derived from the ocean bottom. It has also been observed that coastal storm erosion of barrier beaches and spits leads to increased deposition of sand in lagoons and estuaries behind the barriers. We should expect, therefore, that the tidal projects will increase the deposition in our harbors, mooring basins and some navigation channels.

In light of my previous testimony on beach recession, those harbor and channel areas which have been dredged in coarse-grained back barrier embayments will experience more frequent shoaling. Areas such as Wellfleet Harbor, Gloucester Harbor, Hampton Harbor, Wells, Camp Ellis in the Saco River, and the Scarborough River, for example, will require more frequent dredging than in the past.

The 30 cm. increase in tidal range projected as an effect of the power projects will allow coastal storm waves to erode offshore bottom areas never before affected as well as an increased expenditure of energy on bottom areas which have been affected in the past. This increased erosion capability coupled with the increased storm surge penetration will result in greater amounts of suspended sediment being delivered to sheltered navigation waters dredged into fine-grained subtidal and intertidal flats.

Some harbors and navigation channels will be unaffected, as the "Preliminary Assessment" indicates that flushing rates will increase in estuaries, transporting more suspended sediment seaward than is now presently the case. Deposition of fine-grained sediments in well-stratified estuaries, however, should increase. In some instances, deposition in these types of estuaries will be in areas where deposition does not now occur as the salt wedge will penetrate further landward due to the increased tidal range.

Consequently, some harbor areas such as Portsmouth, Portland, Royal River, and Winterport (Penobscot River) which are well-stratified and historically have had fine-grained material dredged from their waterways should require dredging more often and in different areas than in the past.

It is not possible to be at all quantitative in determining the amount of increased deposition that will occur in these harbor areas -- our research data base in this area is not as sizeable as the beach recession base. Suffice to say, if the tidal power projects are to be reality, this problem will have to be studied much more closely.

SUMMARY

The projected Canadian tidal power projects will cause a 15 cm. increase in storm surge levels within the Gulf of Maine. This will lead to a significant increase in the number of storms which have caused serious beach erosion or damage to shorefront structures in the past as well as an increase in the magnitude of erosion and damage.

These more frequent damaging storms will increase the amount of beach recession by a factor of 1.5 to 2.5; and cause an increase in deposition of sediment in some of our harbors requiring the need for more frequent dredging than in the past.

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Testimony of
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Before the
SENATE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
July 25, 1983
Augusta, Maine

I. INTRODUCTION

I am Alison Rieser, Director of the Marine Law Institute of the University of Maine School of Law and the University of Southern Maine Center for Research and Advanced Study, Portland, Maine. The Institute has, for the last year, been engaged in a cooperative research project with the Complex Systems Research Center of the University of New Hampshire and the Dalhousie Ocean Studies Programme in Halifax, Nova Scotia, to investigate the international environmental risks of coastal energy development in the Gulf of Maine-Bay of Fundy region. Funding for the American research is provided by the William H. Donner Foundation, which has a special interest in issues of significance to both the United States and Canada and to the relationship between the two countries. With me today is Dr. Judith Spiller of the University of New Hampshire, my colleague on the Donner research project.

The province of Nova Scotia and the states of Maine and New Hampshire share the Gulf of Maine-Bay of Fundy system as a common resource and coastal boundary that serves as our laboratory for investigating oceans issues of interest to all three institutions. The Gulf of Maine-Bay of Fundy region constitutes an interrelated, highly dynamic marine system where resource uses or activities in one location are likely to affect uses and activities elsewhere in the system. Present difficulties between the U.S. and Canada in achieving joint or cooperative management of resources there are reflected in the referral of the Gulf of Maine boundary delimitation to the International Court of Justice and in the conflict over oil tanker passage through Canadian waters to the once-proposed Pittston oil refinery at Eastport, Maine.

Law and policy in the area of responsibility regarding prevention of transboundary environmental effects are not well-developed, even for the more traditional kinds of environmental impacts such as air or water pollution. The Fundy Tidal Power proposal represents a new class of environmental questions. It provides an excellent opportunity to examine the special problems that arise when a complex environmental system shared by two countries is the environmental medium of concern and where the environmental impacts are highly uncertain and indirect in nature.

My remarks will address the opportunities for assessing the transboundary environmental effects of tidal power within the existing frameworks of international law, domestic law in the United States and Canada and our bilateral relationship through the International Joint Commission. I will then offer some recommendations for improving our resource management capabilities for transboundary areas. Dr. Spiller will then address some of the problems confronting decisionmakers for Fundy Tidal Power due to the nature of the underlying scientific information.

II. EXISTING OPPORTUNITIES FOR CONSIDERATION OF ENVIRONMENTAL IMPACTS OF FUNDY TIDAL POWER

A. International Environmental Law

International law currently imposes upon each nation the obligation not to use or permit the use of its territory in a manner which causes environmental damage to another nation. Alternatively, it can be said that international law recognizes the right of a nation to be free of transboundary environmental damage. The United States and Canada, through their words and actions, have indicated their agreement with this statement of the law. For example, a restatement of these principles embodied in the Stockholm Declaration of the 1972 U.N. Conference on the Human Environment was explicitly endorsed by U.S. and Canadian officials in a joint communique.

While a nation's substantive environmental rights are triggered by the breach of this obligation, international law is less clear on the responsibility of a nation creating potential environmental injury to prevent that damage from occurring. A number of sources describe a procedural obligation on the part of the acting country to notify and consult with the threatened country as a means of preventing transboundary damage. The United States and Canada appear to recognize at least an obligation to inform the other of projects with potential for environmental injury; the parameters of the notification duty are uncertain, however, at best amounting to a moral or political duty to respond to requests for information. U.S.-Canadian practice is even less clear on the duty of consultation (the duty to discuss proposed activities with a view to modifying them to accomodate the interests of the potentially-affected country), although as members of the OECD they have agreed in principle to engage in consultation.

On the state-provincial level, the Governors of the New England states and the Premiers of the eastern provinces of Canada have recognized the importance of prior notice and consultation concerning energy projects with potential for transboundary impacts. In an Energy Resolution adopted August 17, 1973, a permanent joint committee of the Conference of New England Governors and Eastern Canadian Premiers agreed to

exchange information "relating to all types of energy supplies and energy needs in both regions on a continuing basis" and "regarding environmental problems and the ways in which they may be minimized." However, absent clearer evidence of the positions of the United States and Canadian national governments, it must be said that international law does not currently appear to offer before-the-fact protections adequate to prevent the occurrence of transboundary environmental damage.

B. Domestic Institutions

1. United States

Domestic legislation in the United States and Canada providing for environmental review of certain projects does not appear adequate to address transboundary impacts of Fundy Tidal Power. It is uncertain whether the involvement of United States utilities in Fundy Tidal Power would be subject to the requirements of NEPA. Similarly, it is uncertain whether the Canadian environmental review process would include adequate review of transboundary impacts.

Existing U.S. environmental review of United States utilities' participation in Fundy Tidal Power would be via the Presidential Permit process for a transboundary transmission line administered by the U. S. Department of Energy. While environmental impact statements are commonly prepared for such lines, there is a real question whether such a statement would be required to investigate the impacts of the tidal power

project itself which supplies the power to be carried by the lines. This uncertainty exists even though the current proposal is to export 90% of the power produced by the Fundy Tidal Power project to New England and New York and funding provided by United States utilities (through guaranteed purchase contracts or capital investment) may be an economic prerequisite to development of Fundy Tidal Power. In general, regulation of power exports is much more pervasive than regulation of power imports. Congress should consider the need for legislation assuring that the full policy implications, including environmental impacts, are considered before a utility can enter into a contract for energy imports.

The General Accounting Office took a similar position in its September 20, 1982 report titled "Clear Federal Policy Guidelines Needed for Future Canadian Power Imports." The GAO specifically recommended that the "the Secretary of Energy work with the executive subcabinet working group on regulation, competition, and efficiency in the electric utility industry to establish clear Federal policy guidelines towards Canadian power imports." We agree with the GAO that the national energy policy should be examined and that the existing Presidential permit process is deficient in operation because it lacks an explicit policy basis. However, we also found the GAO report deficient in in its failure to give sufficient consideration to potential transboundary environmental effects of the energy

facilities themselves. It failed to mention possible transboundary environmental problems, although it touched on environmental impacts and raised questions concerning such issues as energy security and national security concerns.

Fundy Tidal Power presents a clear example of the case where the full picture needs to be examined: not only imported power v. domestic production, but also the impacts within the United States of the energy facility itself.

State environmental regulation similarly appears not to extend to the environmental impacts of extraterritorial activity. For example, state environmental review pursuant to Maine's Site Location of Development Act is also untested as a forum for investigation of impacts of a project where only the power lines will be sited in Maine.

Failure to exercise controls over energy import activities by United States utilities, in addition to failing to prevent possible environmental damage in the United States, could affect the United States' exercise of its rights to be free of transboundary injury. Under existing and developing theories of international law, the failure to regulate foreign activities of domestic entities, which the United States knows or should know could result in environmental damage in the United States, could result in the United States being held to have consented to the production of such damage and the waiving of the right to compensation.

2. Canada

It is important to note that although the Fundy Tidal Power Corporation has made a commitment to submit to full environmental review under the Canadian Environmental Review Process (EARP), because of the Corporation's status as a Crown Corporation, its participation is not mandated, but is voluntary.

Analysis of the EARP process and other Canadian environmental reviews suggests that perhaps the most successful environmental review in terms of both quality of scientific basis and agreement on and implementation of measures based on the scientific conclusions, was performed by the Peace/Athabasca Delta Study Group. This study of the impacts on downstream biota of the construction of a dam involved the use of a comprehensive simulation model to investigate successional changes in delta habitat. It serves as an interesting model 1) because the study in question was not called for by any governmental process-it pre-dated EARP- but was performed cooperatively by government scientists at the federal and provincial levels, and 2) because the concern on the project in question was environmental effects in Alberta from construction of a dam in British Columbia - transboundary effects within the Canadian federal system.

It appears that opportunities for United States participation in the EIA process, either by governmental officials or individual citizens, would be at the discretion of the federal and provincial officials conducting the reviews. The scope of review and the weight to be given transboundary effects is uncertain. For example, the 1982 EARP "Guidelines for the Preparation of an Environmental Impact Statement - The Beaufort Sea Hydrocarbon Production Proposal" provided for EIS consideration of potentially significant effects in the coastal waters of Alaska and Greenland but noted that "possible effects in these areas cannot be examined by the panel to the same degree of detail as those effects occuring inside Canadian jurisdiction." The quality of EARP review cannot, as under our NEPA process, be tested in the courts.

C. Bilateral Arrangements

One existing mechanism which would, if both countries chose to utilize it, examine the transboundary implications of Fundy Tidal Power, is the reference process by the International Joint Commission (IJC) under Article IX of the Boundary Waters Treaty of 1909. The two-stage reference process has the advantage of developing an agreed-upon scientific data base, specifically concerned with transboundary impacts and jointly produced by experts from both countries, and of providing for preparation of policy recommendations on the basis of these data, by an impartial, bilateral body. The Commission has

handled references in the past concerning transboundary impacts in projects as complex as the present, and with data analysis similarly as sophisticated as that which would be required here. In particular, references have involved prediction of transboundary impacts on the basis of computer modelling, just as would be involved in a Fundy Tidal Power reference. The IJC functions well when called upon to consider the existing body of scientific and technical information and to make judgments about what information is most relevant to the question of environmental impact. This ability is particularly valuable when complex ecosystems such as the Gulf of Maine -- Bay of Fundy region are involved.

One recent example of the functioning of the reference process was in the case of the highly controversial Garrison Diversion Unit. Garrison, a large irrigation project being developed by the Bureau of Reclamation in North Dakota, spawned concern in Canada that the project would cause water quantity and quality problems in Manitoba, and, as a result of its potential inter-basin transfer of fish species, diseases and parasites, would damage important recreational and commercial fisheries. The investigation of the potential transboundary impacts of Garrison included the use of a sophisticated computer model developed by the Bureau of Reclamation to predict the quantity and quality of irrigation return flows. On the basis of its international study board's scientific

investigations, the Commission recommended that those portions of Garrison which would potentially impact Canadian water quality not be constructed. Although the Commission's recommendations were strongly criticised by Garrison's supporters, the study board's scientific analysis has served as the basis for subsequent bilateral negotiations. At present, the United States has decided to modify the project to accomodate many of the concerns raised by the Commission, and has revised the construction plans to postpone development, pending completion of discussions with Canada, of those portions of the project which would affect Canadian water quality.

In addition, it should be remembered that the IJC in the past investigated tidal power under the terms of a United States-Canada reference. When the joint Passamoquoddy Tidal Power project was under consideration in the 1960's, the Commission conducted a reference on the economic feasibility of the project and the potential harm to Bay of Fundy fisheries.

The terms of a new reference, perhaps in the form of mutually agreed upon guidelines for the investigations and decisionmaking, could build upon past references and serve as a model for future protocols dealing with analogous transboundary problems where the two nations need to arrive at mutually agreeable solutions to foster a satisfactory relationship. However, two important drawbacks exist for the reference

process. One is the fact that IJC recommendations are just that - recommendations. Ultimately, the two governments would have to make their own decisions and come to some agreement through usual governmental and diplomatic channels. The other is the fact that, in practice, a reference is initiated only on the joint request of both governments. Thus, use of the reference process and the application of its results are dependent on political factors within the adminstrations of both countries.

III. RECOMMENDATIONS

Based on the foregoing observations about the current institutional arrangements for examining transboundary environmental impacts of proposed projects, we offer the following recommendations:

A. Domestic Legal Framework

1. United States

Legislation should be considered requiring a license for the import of power (including power resources, i.e., natural gas pipelines), and requiring the conditioning of the license on arrangements to protect United States environmental interests; this latter mechanism would have the added advantage of triggering the requirement of preparation of an environmental impact statement. The legislation should probably make explicit the requirement that the EIS consider impacts on both sides of the international boundary.

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Alternatively, or in addition, the Council on Environmental Quality (CEQ) regulations on environmental impact statements should be amended to define "transboundary regions" and to require consideration of effects of federal actions across the boundary (including such effects as long-range or indirect impacts). If these EIS content provisions are triggered, special procedures for intergovernmental consultation should be specified and required.

2. Canada

The EARP procedures should be amended and generic guidelines established applicable to all projects to accomplish the same objectives.

B. Bilateral

The Administration should be urged to enter into negotiations with the Canadian government toward the submission to the IJC of a reference on the transboundary implications of the Fundy Tidal Power project. Where such a reference is made, the reports of the IJC and its study board, along with the final IJC recommendations should be incorporated into any EIS or environmental assessment prepared on the transboundary impacts, both as part of the technical information concerning the environmental effects and as one of the alternative courses of action explored in the impact statement.

C. International Legal Framework

The President and State Department and the Premier and Office of External Affairs should take the opportunity to make explicit their belief that the two countries are bound by an international law obligation to notify and consult on projects with potential transboundary impacts, and to specify the procedures to be followed in such cases (perhaps incorporating by reference the recommended NEPA and EARP procedures).

MARINE LAW INSTITUTE
246 Deering Avenue, Portland, Maine 04102, 207/780-4474

August 28, 1983

Senator George J. Mitchell
SR 364, Russell Office Building
Washington, D.C. 20510

Dear Senator Mitchell:

Enclosed is the legislative proposal to regulate electrical energy imports that you requested at the July 25 field hearing of the Senate Committee on Environment and Public Works in Augusta, Maine. The legislation proposes amendment of § 202 of the Federal Power Act, 16 U.S.C. § 824a, by the addition of a new subsection (h). The purpose of the proposal is to give the Secretary of the Department of Energy the authority to review imports of electrical energy just as the Secretary currently reviews exports pursuant to 16 U.S.C. § 824a(e). The proposed legislation parallels that provision, (copy attached to enclosed explanatory memorandum as Exhibit 1) except that the proposed legislation explicitly references compliance with the National Environmental Policy Act and also changes the presumption on the "public interest" test, for the reasons discussed in the attached memorandum.

Our recommendation for such legislation is based on our analysis of existing United States regulatory authority applicable to Nova Scotian Tidal Power development. Our conclusion is that timely environmental review of the impacts in the United States from construction and operation of the project is problematic under existing statutes.

As noted in our field hearing testimony, the only existing federal authority for regulation of power imports is through the Presidential Permit process for authorizing construction, operation, and connection at the borders of the United States of electrical transmission lines and natural gas pipelines, authorized by Executive Order 10485 (Sept. 3, 1953) (copy attached to this memorandum as Exhibit 2). This provides only indirect and uncertain leverage for review of the domestic environmental impacts of an electrical generating facility constructed abroad.

This proposal is directed primarily at assuring examination of the environmental impact of electrical energy imports. However, as we noted in our testimony, a recent GAO report,

"Clear Federal Policy Guidelines Needed for Future Power Imports" (1982) recommends that, in addition to environmental impacts, the Administration also examine such issues as appropriate levels of imports for reliability and national security.[1] See 42 U.S.C. §§ 7111, 7112 (10) and (13). While we have not explicitly considered or addressed these issues, they should certainly be examined and regulated by the Secretary under the proposed legislation as part of the "public interest" review.

Testimony given by the Marine Law Institute and others at the field hearing, this letter, and the attached memorandum and exhibits should be regarded as background for the legislation.

The Marine Law Institute is considering sponsoring a workshop this fall to evaluate this legislative proposal and receive input from other institutions and experts in the field. We would be happy to respond to any comments or questions you have regarding the proposal.

Sincerely yours,

Alison Rieser

Alison Rieser,
Director

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1 The primary recommendation of the GAO report was that the executive subcabinet group on Regulation, Competition, and Efficiency in the Electric Utility Industry "establish clear Federal policy guidelines on the role for future Canadian Electricity in the United States." In June, 1983, DOE issued a report The Future of Electric Power in America: Economic Supply for Economic Growth, as an outgrowth of its work with that group. The report contains only a brief consideration of Canadian imports (Id. at 4-30 - 4-32), no policy recommendations or guidelines, and no time table for production of the follow-up report that might contain such guidelines (Id. at ii, and personal communication with David Meyer, Electric Utilities Division of the Office of Policy, Planning and Analysis, DOE, August 22, 1983). Furthermore, the group, or at least DOE, which chairs the group, is giving little or no attention to the environmental aspects of electric power policy (D.O.E. report at iii).

AR:bb-s

Marine Law Institute Legislative Proposal

A BILL

To amend the Federal Power Act of 1920.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, that this Act may be cited as the "Electrical Energy Imports Amendments Act of 1983."

SEC. 2. IMPORT PERMIT PROGRAM

Section 202 of the Federal Power Act of 1920 (16 U.S.C. Section 824a) is amended --

(1) by adding at the end thereof the following new subsection:

"(h) No person shall transmit or enter into agreement for the transmission of any electric energy into the United States from a foreign country without first having secured an order of the Secretary of Energy authorizing it to do so. The Secretary shall issue such order upon application, after opportunity for public hearing and upon compliance with the requirements of the National Environmental Policy Act of 1969, if he finds that the proposed transmission is consistent with the public interest.

The Secretary may by order grant such application in whole or in part, with such modifications and upon such terms and conditions as the Secretary may find necessary or appropriate, and may from time to time, after opportunity for hearing and for good cause shown, make such supplemental orders as he may find necessary or appropriate."; and

(2) by inserting "or (h)" immediately after "subsection (e)" in the final sentence of subsection (f).

MEMORANDUM

TO: Senator George Mitchell, Senate Committee on Environment and Public Works

FROM: Marine Law Institute, University of Maine School of Law

RE: Explanation of Proposed Legislation Amending Section 202 of the Federal Power Act to Regulate Imports of Electric Energy

The question may arise why, rather than proposing a new subsection (h) to section 202 of the Federal Power Act, one does not simply amend the first sentence of subsection (e) to cover imports as well as exports by giving the Secretary of Energy[1] the power to authorize the transmission of electricity to or from a foreign country. The reason is that the text of the proposed new subsection (h) contains several significant differences from subsection (e), for the reasons explained herein.

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1 The term Commission in § 824a refers to the Federal Power Commission. The Secretary of the Department of Energy has succeeded to the authority pursuant to 16 U.S.C. § 824a(e) formerly vested in the Commission. Sections 301(b) and 402(f), Department of Energy Organization Act, Pub. L. 95-91, 91 Stat. 577, 583, 42 U.S.C. §§ 7151(b) and 7172(f). Pursuant to § 206(b) of the DOE Organization Act, 42 U.S.C. § 7136, the Secretary may delegate such functions as he may consider appropriate to the Economic Regulatory Administration (ERA). It is anticipated that such a delegation would be made with respect to the proposed legislation as Department of Energy Delegation Order (D.O.) No. 0204-4, para. 7, delegates to the Administrator of ERA authority over "the exportation and importation of electric energy, pursuant to the provisions of Section 202(e) of the Federal Power Act..., as amended, and Executive Order No. 10485."

1. "No person shall transmit or enter into agreement for the transmission of any electric energy into the United States..."

It is our intention that this legislation trigger environmental review at the earliest possible stage in the import process in order to identify environmental impacts in the United States from construction and operation of a foreign facility before conclusion of a final contract for import of electrical energy. At least in the case of Fundy tidal power, the Tidal Power Corporation has indicated that "ironclad contracts" for the sale of output would be a prerequisite to project financing and construction. Tidal Power Corp., Update '82, p.6. Thus review of import agreements should provide timely pre-construction review of foreign energy facilities being built solely for export.

The word "agreement" rather than "contract" was selected in the proposed legislation with the intention of triggering review prior to the final contract stage. For example, the "Chronology of Events NEPOOL/Hydro-Quebec Project" issued as part of the New England Governor's Conference Press Release, March 21, 1983, (copy attached as Exhibit 3) indicates that NEPOOL participants signed a "preliminary support agreement ... authorizing the beginning of licensing procedures" in May of 1981, after which both Hydro-Quebec and NEPOOL began the permitting process; NEPOOL participants signed project support agreements in December 1981; Hydro-Quebec and NEPOOL signed an "agreement in principle" on the three contracts" in June 1982;

and the formal signing of contracts by NEPOOL and Hydro-Quebec finally occurred in March, 1983. In this instance, signing of the final contract has occurred well before commencement of construction of the transmission lines, which has not yet begun. Presumably, as with Fundy tidal power, contracts would also be signed before construction of a power plant for export would begin; but it would be preferable if environmental review were commenced well before that date. Use of the term "agreement" would assure initiation of the environmental review process at least by the time of a conditional agreement between the parties to enter into contracts. Department of Energy regulations could define what would constitute an "agreement" for purposes of this provision.

We note that the Federal Energy Regulatory Commission (FERC) regulations promulgated pursuant to Section 202(e) of the Federal Power Act[2] for governing export permits provide, inter alia:

> The owner of a source of supply of electric energy who proposes to transmit any portion of such energy from the United States to a foreign country or who has

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2 Although these regulations appear in the most current edition of the Code of Federal Regulations, they apparently have no applicability and should have been deleted -- from the 1978 C.F.R. edition on. The Department of Energy Reorganization Act, Pub. L. 95-91, 91 Stat. 567 (42 U.S.C. § 7101 et seq.) passed in 1977 delegated to the Secretary of Energy, not to the Federal Energy Regulatory Commission (FERC) the authority over exports previously held by the Federal Power Commission pursuant to § 202(e) of the Federal

entered or proposes to enter into a contract for the sale of electric energy to be so transmitted, and the transmitter thereof, are necessary parties to an application for the authorization sought under this rule. (emphasis added)

18 C.F.R. § 32.30. Although this provision is concerned with who would be necessary parties to an application, the emphasized language indicates similar concern for precontract review of transboundary electricity transmissions.

2. "... only if he finds the proposed transmission is consistent with the public interest"

The proposed legislation changes the standard of review from the limited standard of subsection (e), requiring issuance of the order unless there is a finding that "the proposed

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[2](cont'd) Power Act. In 1977 The Secretary of Energy delegated to the Administrator of the Economic Regulatory Administration (ERA) authority to issue orders authorizing the export of electric energy pursuant to § 202(e). DOE D.O. No. 0204-4, para. 7 (1977) reprinted at 10 C.F.R. § 1001.1, Appendix. Paragraph 6 of that Delegation Order authorizes ERA to issue export and import orders for natural gas. Subsequent DOE Delegation Orders have amended the 1977 D.O., but only with respect to natural gas. DOE D. O. Nos. 0204-25 and 0204-26 (1978) direct both ERA and FERC to review export authorizations of natural gas. Since the 1977 DOE D.O. has not been similarly amended for electricity exports, ERA retains complete jurisdiction over authorization of electrical exports. 10 C.F.R. § 205.300, which sets forth the regulations for application to ERA under § 202(e), does not contain the language quoted in the text above. These Title 10 ERA requirements supersede Title 18 C.F.R. § 32.30 providing for application to the Federal Power Commission, and the continued reprinting of the FERC regulations is apparently an oversight. (Personal communication with Bernard Cogan, Office of Ass't General Counsel, Electric Rates and Corporate Regulation, FERC, DOE, August 17, 1983.)

transmission would impair the sufficiency of electric supply within the United States or would impede or tend to impede the coordination in the public interest of facilities subject to the jurisdiction of the Commission," to a broader "public interest" standard of review.

The decision of the United States Court of Appeals for the District of Columbia in Distrigas Corp. v. Federal Power Commission, 495 F.2d 1057 (D.C. Cir.), cert. denied, 419 U.S. 834 (1974), explains the scope of the public interest regulation. In that case the Commission was concerned that its review of the import of natural gas might be limited, unless the term 'interstate commerce' were construed to include 'foreign commerce', a construction precluded by the court's holding in Border Pipe Line v. Federal Power Commission, 171 F.2d 149 (D.C. Cir. 1948). The Distrigas court declined to overrule Border Pipe Line, but found the Commission could achieve its desired ends under section 3 of the Natural Gas Act (NGA) (15 U.S.C. § 717b). This provision closely parallels Section 202(e) of the Federal Power Act (16 U.S.C. § 824a(e)), except that Section 3 of the NGA deals with imports, as well as exports, of natural gas, while Section 202(e) of the FPA deals only with exports of electricity. The court in Distrigas concludes that the authority granted the Federal Power Commission over natural gas imports under Section 3, NGA "is at once plenary and elastic" and that

> Section 3 supplies the Commission not only with the power necessary to prevent gaps in

> regulation, but also with flexibility in exercising that power -- flexibility far greater than would be the case were we to hold that imports are interstate commerce, automatically and compulsorily subject to the entire panoply of Section 7's [15 U.S.C. § 717f] requirements.[3]

Id. at 1064.

The drafters felt that the Secretary should authorize importation of electricity only after consideration of all factors affecting the public interest, e.g., environmental impacts, not just energy supply and coordination issues. The opinion in Distrigas, supra, 105, notes that one of the purposes behind federal regulation of natural gas under the NGA, including regulation of imports, was to complement, not duplicate, state regulations and to assure that there were no gaps in regulation "through which private interests could subvert the public welfare."

Since the passage of the National Environmental Policy Act of 1969 (NEPA), the 'public interest' or 'public welfare' has been defined to include protection of the environment.[4]

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3 This interpretation was recently reaffirmed by the District of Columbia Circuit in its opinion in West Virginia Public Services Com'n v. D.O.E., supra.

4 See definition of public interest in Udall v. Federal Power Commission, 387 U.S. 428, 450 (1967). Although that case involved licensing of a hydroelectric dam, where the more specific standards of 16 U.S.C. § 803(a) also apply, the opinion speaks to the definition of public interest:

> The test is whether the project will be in the public interest. And that determination can be made only after exploration of all issues relevant to the public interest including future power demand and supply, alternate sources of power, the public interest in

However, NEPA itself is only triggered, when there is federal action 'significantly affecting the human environment.' An import authorization would be such a federal action, which would trigger NEPA review and preparation of an environmental impact statement if the importation would significantly affect the quality of the human environment. Without such an import authorization, there exists the sort of regulatory gap that the Federal Power Act was designed to fill. See 1953 U.S. Code Cong. & Ad. News 2164, 2166; H.R. No. 978, 83d Cong., 1st Sess. Obviously, regulation of imports is a federal, rather than a state, function. See id. at 2169; Distrigas supra at 1063.

The proposed legislation also changes the standard of review from the "negative standard" used in subsection (e) to a "positive standard." While it is not clear that there is any difference under a negative "unless" standard and a positive "only if" standard in terms of the authority of the Secretary to attach appropriate terms and conditions to a permit (see Distrigas supra; Compania de Gas de Nuevo Laredo, Inc., 59 FPC 2318, 2329 (1975), aff'd, 606 F.2d 1024 (D.C. Cir. 1979)), there is a difference in presumptions and burden of proof that

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[4](cont'd) preserving reaches of wild rivers and wilderness areas, the preservation of anadromous fish for commercial and recreational purposes, and the protection of wildlife.
We intend the term "public interest" here to be equally broadly construed.

is not insignificant. This distinction was noted in discussing regulation of imports under the Natural Gas Act (NGA) in West Virginia Public Services Com'n v. United States Department of Energy, 681 F.2d 847, 856 (D.C. Cir. 1982):

> Contrary to section 7 [NGA, 15 U.S.C. § 717(f)],[5] however, section 3 sets out a general presumption favoring such authorization [of imports and exports], by language which requires approval of an application unless there is an express finding that the proposed activity would not be consistent with the public interest. Section 3 therefore differs significantly from other sections under the NGA which condition agency approval upon a positive finding that the proposed activity will be in the public interest.

The importation of electrical energy should be held to the same public interest standard as is authorization of such domestic activities as, e.g.: construction or enlargement of natural gas facilities (15 U.S.C. § 717f(e)), construction of hydroelectric projects (16 U.S.C. § 797(e)), or physical interconnection of transmission facilities (16 U.S.C. § 824a(b)).

3. "... after opportunity for public hearing and compliance with the requirements of the National Environmental Policy Act of 1969 ..."

The proposed legislation specifically references NEPA because of the concerns that environmental aspects of the public interest review may otherwise be overlooked. While the

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5 Footnote 36 to the quoted passage explains: "An application under section 7, for example, may be granted only if the activity 'is or will be required by the present or future public convenience and necessity.' 15 U.S.C. § 717f(e) (1976)."

current DOE regulations governing Presidential Permits specifically require "information regarding environmental impacts for each routing alternative" for transboundary transmission lines (10 C.F.R. § 205.322(c)), the regulations governing applications for export permits do not routinely require information regarding environmental impacts associated with export. Cf. 18 C.F.R. Part 153 regarding export/import and Presidential Permits for natural gas. Probably import/export projects were perceived as having no environmental impacts in the United States other than those of the utility lines. In any event, the environmental impacts of domestic generating facilities that export electricity are not within the jurisdiction of the Department of Energy. 16 U.S.C. § 824(b). Such facilities would generally require federal air pollution licenses or other permits that would subject them to environmental review. This is not the case for foreign facilities constructed for export.

Current conditions make it increasingly likely that energy facilities, including tidal power, coal, and nuclear plants, may be constructed or operated for export by our neighbors close enough to our borders to have potentially significant impacts on air and water quality in the United States. Therefore our domestic legislation should provide for consideration of these impacts before allowing import of the power by domestic companies.

4. General Permits and Permit Consolidation

It is not intended that the proposed legislation impose any undue regulatory burdens on importers of electricity. In drafting the proposed legislation, consideration was given to including a provision authorizing the issuance of general permits, e.g., for diversity or economy energy exchanges over existing lines. Cf. The general permit provision in § 404(e) of the Clean Water Act, 33 U.S.C. § 1344(e). This possibility was rejected because it was felt that such activities should receive public interest consideration, and that appropriate adjustments in application requirements could be made by regulation. Cf. 10 C.F.R. § 205.301 and discussion thereof in the preamble to the Federal Register notice accompanying adoption of that regulation, 45 Fed. Reg. 71558, 71559 (October 28, 1980). Obviously, however, those entering into contracts for diversity exchanges should have consolidated import-export proceedings. Similarly, applications for import authority and a presidential permit should be consolidated when appropriate. The regulations should so provide.

EXHIBIT 1

Transmission of electric energy to foreign country

(e) After six months from August 26, 1935, no person shall transmit any electric energy from the United States to a foreign country without first having secured an order of the Commission authorizing it to do so. The Commission shall issue such order upon application unless, after opportunity for hearing, it finds that the proposed transmission would impair the sufficiency of electric supply within the United States or would impede or tend to impede the coordination in the public interest of facilities subject to the jurisdiction of the Commission. The Commission may by its order grant such application in whole or in part, with such modifications and upon such terms and conditions as the Commission may find necessary or appropriate, and may from time to time, after opportunity for hearing and for good cause shown, make such supplemental orders in the premises as it may find necessary or appropriate.

Transmission or sale at wholesale of electric energy; regulation

(f) The ownership or operation of facilities for the transmission or sale at wholesale of electric energy which is (a) generated within a State and transmitted from that State across an international boundary and not thereafter transmitted into any other State, or (b) generated in a foreign country and transmitted across an international boundary into a State and not thereafter transmitted into any other State, shall not make a person a public utility subject to regulation as such under other provisions of this subchapter. The State within which any such facilities are located may regulate any such transaction insofar as such State regulation does not conflict with the exercise of the Commission's powers under or relating to subsection (e) of this section.

June 10, 1920, c. 285, § 202, as added Aug. 26, 1935, c. 687, Title II, § 213, 49 Stat. 848, and amended Aug. 7, 1953, c. 343, 67 Stat. 461.

Historical Note

1953 Amendment. Subsec. (f). Act Aug. 7, 1953 added subsec. (f).

Transfer of Functions. All executive and administrative functions of the Federal Power Commission were, with certain reservations, transferred to the Chairman of such Commission, with authority vested in him to authorize their performance by any officer, employee, or administrative unit under his jurisdiction, by 1950 Reorg.Plan No. 9, §§ 1, 2, eff. May 24, 1950, 15 F.R. 3175, 64 Stat. 1265, set out as a note under section 792 of this title.

Delegation of Functions. Functions of the President respecting certain facilities constructed and maintained on United States borders delegated to the Secretary of State, see Ex.Ord.No.11423, Aug. 16, 1968, 33 F.R. 11741, set out as a note under section 301 of Title 3, The President.

Legislative History. For legislative history and purpose of Act Aug. 7, 1953, see 1953 U.S.Code Cong. and Adm.News, p. 2164.

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EXHIBIT 2

Executive Order 10485—Providing for the performance of certain functions heretofore performed by the President with respect to electric power and natural gas facilities located on the borders of the United States

SOURCE: The provisions of Executive Order 10485 of Sept. 3, 1953, appear at 18 FR 4957, 3 CFR, 1949–1953 Comp., p. 970, unless otherwise noted.

WHEREAS section 202(e) of the Federal Power Act, as amended, 49 Stat. 847 (16 U.S.C. 824a(e)), requires any person desiring to transmit any electric energy from the United States to a foreign country to obtain an order of the Federal Power Commission authorizing it to do so; and

WHEREAS section 3 of the Natural Gas Act, 52 Stat. 822 (15 U.S.C. 717b), requires any person desiring to export any natural gas from the United States to a foreign country or to import any natural gas from a foreign country to the United States to obtain an order from the Federal Power Commission authorizing it to do so; and

WHEREAS the proper conduct of the foreign relations of the United States requires that executive permission be obtained for the construction and maintenance at the borders of the United States of facilities for the exportation or importation of electric energy and natural gas; and

WHEREAS it is desirable to provide a systematic method in connection with the issuance and signing of permits for such purposes:

NOW, THEREFORE, by virtue of the authority vested in me as President of the United States and Commander in Chief of the armed forces of the United States, it is hereby ordered as follows:

SECTION 1. (a) The Secretary of Energy is hereby designated and empowered to perform the following-described functions:

(1) To receive all applications for permits for the construction, operation, maintenance, or connection, at the borders of the United States, of facilities for the transmission of electric energy between the United States and a foreign country.

(2) To receive all applications for permits for the construction, operation, maintenance, or connection, at the borders of the United States, of facilities for the exportation or importation of natural gas to or from a foreign country.

(3) Upon finding the issuance of the permit to be consistent with the public interest, and, after obtaining the favorable recommendations of the Secretary of State and the Secretary of Defense thereon, to issue to the applicant, as appropriate, a permit for such construction, operation, maintenance, or connection. The Secretary of Energy shall have the power to attach to the issuance of the permit and to the exercise of the rights granted thereunder such conditions as the public interest may in its judgment require.

(b) In any case wherein the Secretary of Energy, the Secretary of State, and the Secretary of Defense cannot agree as to whether or not a permit should be issued, the Secretary of Energy shall submit to the President for approval or disapproval the application for a permit with the respective views of the Secretary of Energy, the Secretary of State and the Secretary of Defense.

[Sec. 1 amended by EO 12038 of Feb. 3, 1978, 43 FR 4957, 3 CFR, 1978 Comp., p. 136]

SEC. 2. [Deleted]

[Sec. 2 deleted by EO 12038 of Feb. 3, 1978, 43 FR 4957, 3 CFR, 1978 Comp., p. 136]

SEC. 3. The Secretary of Energy is authorized to issue such rules and regulations, and to prescribe such procedures, as it may from time to time deem necessary or desirable for the exercise of the authority delegated to it by this order.

[Sec. 3 amended by EO 12038 of Feb. 3, 1978, 43 FR 4957, 3 CFR, 1978 Comp., p. 136]

SEC. 4. All Presidential Permits heretofore issued pursuant to Executive Order No. 8202 of July 13, 1939, and in force at the time of the issuance of this order, and all permits issued hereunder, shall remain in full force and effect until modified or revoked by the President or by the Secretary of Energy.

[Sec. 4 amended by EO 12038 of Feb. 3, 1978, 43 FR 4957, 3 CFR, 1978 Comp., p. 136]

SEC. 5. Executive Order No. 8202 of July 13, 1939, is hereby revoked.

EXHIBIT 3

Chronology of Events
NEPOOL/Hydro-Québec Project

November 1979	Formation of a joint NEPOOL/Hydro-Québec technical committee to study the feasibility of interconnection.
July 1980	Start of negotiations between NEPOOL and Hydro-Québec.
September 1980	First formal report issued by the joint technical committee which stated the economic and technical advantages to both systems.
May 1981	Preliminary support agreement signed by NEPOOL participants authorizing the beginning of licensing procedures.
November 1981	Applications for licenses and permits filed with the New Hampshire Department of Public Utilities and Site Evaluation Committee.
November 1981	Hydro-Québec asks the Québec government for authorization to carry out preliminary studies.
December 1981	Applications for licenses and permits filed with the Vermont Public Service Board. Application for presidential permit filed with the U.S. Department of Energy. Public hearings begin in New Hampshire. NEPOOL participants sign project support agreements.
December 1981	Québec government authorization obtained.
February 1982	Public hearings begin in Vermont.
June 1982	Agreement in principle between Hydro-Québec and NEPOOL on the three contracts.
August 1982	U.S. Federal Energy Regulatory Commission approves NEPOOL support agreements.

.../2

December 1982	New Hampshire Department of Public Utilities grants approval for transmission line in New Hampshire.
February 1983	Public Service Board approves construction of transmission line in Vermont.
March 1983	Formal signing of contracts by NEPOOL and Hydro-Québec.
March 1983	Hydro-Québec requests Québec government authorization for construction of the transmission line. Public hearings scheduled for the summer.
March 1983	Hydro-Québec requests National Energy Board export licence, and Certificate of Public Convenience and Necessity. Public hearings scheduled for the fall.
Spring 1984 - October 1986	Construction of transmission line and converter stations.
October 1986	Transmission of electricity to begin.

TESTIMONY OF JUDITH SPILLER
COMPLEX SYSTEMS RESEARCH CENTER
UNIVERSITY OF NEW HAMPSHIRE
BEFORE THE SENATE COMMITTEE ON
ENVIRONMENTAL AND PUBLIC WORKS,

July 25, 1983
Augusta, Maine

My name is Judith Spiller. I hold a Ph.D. in Earth and Space Science and am currently an Assistant Professor of Research at the Complex Systems Research Center at the University of New Hampshire. I wish to address my remarks to some of the constraints concerning predicting the transboundary effects of Fundy tidal power and to whether the body of existing scientific information is sufficient to evaluate the project's risks.

Our research indicates that scientific investigations, growing primarily from the work of the Fundy Environmental Studies Boards adequately address the issues of near-field effects. The same sufficiency does not apply to questions about far-field, transboundary effects; however, we feel as I will discuss that an extensive research program directed specifically at collecting new information concerning the effects of Fundy tidal power will yield little because of the highly dynamic nature of the Gulf of Maine - Bay of Fundy region. Rather, we suggest a mechanism like that involved in IJC deliberations which empanels scientific and technical experts from Canada and the United States to review existing information and to indicate the uncertainties surrounding the effects of Fundy tidal power. Such a panel could distinguish between predictions we can test like effects on shad populations from those we can make with very little assurance like changes in fisheries productivity. Such a bilateral group could

assuage concern that local issues are not being addressed because the activity is occurring in another country, and it could assure that existing research is synthesized so that appropriate information is commonly available for decision makers to utilize in their judgments. Existing decision-making structures with some small modifications exist to evaluate the possible transboundary effects of Fundy tidal power. The difficulty arises because of the large uncertainties, some inherent, about the behavior of the region's physical and biological systems.

As for the constraints in making predictions, let us start by assuming that the principle effect of the projected changes in tidal amplitude resulting from Fundy tidal power will be on coastal property--beaches, salt marshes, and human structures--because of flooding and erosion; and on fisheries resourcess--because of shifts in mixing characteristics and coastal erosion. In order to predict the effects of tidal changes in these two areas, it is necessary first that the changes be detectable (that is, measureably different from what has been observed in the past) and further, that these changes must be attributable to the presence of tidal power barriers in the upper reaches of the Bay.

Attribution and detection essentially establish causality and require that speculated changes from tidal power development be either unique or significantly greater than those observed from existing phenomena. It is generally agreed that changes in tidal amplitude will shift physical and biological parameters but some shifts already occur. For example, storms commonly raise water levels along the coastline, causing varying degrees of destruction, and fisheries abundances of commercial species like hering and sea scallops may exhibit dramatic

year-to-year differences in abundance. Additionally, astronomical and meteorological forces, the degree of solar radiation, the rotation of the earth, and the basic topography of the Bay of Fundy and the Gulf of Maine all structure the hydrodynamics of the Bay-Gulf system, and in turn, influence biological productivity. Thus, these changes are in magnitude rather than in effect and so are not unique.

The Fundy tidal power project may increase storm damage and alter productivity, but whether or not these increases will exceed the natural range of variation in the physical system represents an important question. Changes in both characterize dynamic ecosystems like that of the Bay and the Gulf under normal, average conditions. Some consideration of the many factors influencing the Gulf and Fundy system suggests the wide range of variably commonly encountered here and place perspective on the changes projected for the tidal power project.

If, for example, we assume, as the Greenberg model predicts, that a 30 centimeter (roughly 12 inches) increase in tides will occur along parts of the coast of Maine, would we conclude that the increase would be manifested as a 15 cm higher high tide and a 15 cm lower low tide in the intertidal region. To reach this conclusion, the factors contributing to the level of the sea must be considered. In addition to the lunar tidal effect--the M2 tide--, numerous other astronomical forces operate to magnify or diminish tidal height although the effects of these forces are relatively small compared with the M2 tide. Further, coastal configuration and bottom topography also act to dissipate tidal energy. The continuing rise in sea level, approximately .16 cm per Portland, Maine also contributes to sea level. This change occurs because of subsidence of the New England coast and a

worldwide increase in sea level, resulting from glacial melting. Finally, meteorological forces also exert a strong influence on sea level. Prevailing winds in conjunction wth coastal configuration affect tidal height and current strength. Storms, however, are a dominant influence. Strong winds blowing toward land create frictional stresses on the water column. The resulting storm surges cause the coastal damage associated with large storms. These surges can build waves up to 3.1 meters (10.3 feet) above sea level for a 100 year storm. The passage of a major storm's low pressure center can raise non-tidal sea level by as much as .6 meters (23 inches). This increase also is reflected in the coastal wave heights of storms.

Consequently, a 15 cm increase in tidal height must be evaluated against the contributon to sea level of each of the preceeding. While such an increase would enhance the wave height of a 100 year storm by roughly 10%, this change will be tempered by the direction, the intensity, and the speed of onset of storm conditions. Thus, several factors whose behavior we only crudely understand contribute to enhancing or diminishing the contribution of Fundy tidal power to sea level along the coast.

Predicting actual coastal effects, that is the degree of erosion or flushing, is similarly confounded. While we can, with some accuracy, predict beach erosion given the inclination of the beach, its composition, and the angle of wave attack, the intervening factors mentioned above--coastal configuration, bottom topography, prevailing wind directon, intensity and duraton of storms--all play significant roles and are not quantifiable. Each will influence the total 30 cm tidal range change before that change is translated into intertidal effects.

Assessing the changes in mixing on fishery resources is more difficult still. Areas of turbulent mixing such as the zones of contact between the Gulf of Maine and the Bay of Fundy water masses, or along the coastline correlate with areas of high biological productivity. In such areas, upwelling brings nutrients to the surface; and mixing distributes oxygen in the water column and contributes to more uniform temperatures. In shallow waters, tidal movement aids this mixing. Adjacent areas of non-mixed water become layered with warmer waters on the surface in the summer. Super-imposed on these waters is the dominant counterclockwise residual circulaton of the Gulf of Maine that carries water along the southwestern coast of Nova Scotia, into the eastern side of the Bay of Fundy, out the western side and finally along the coast of Maine. This dominant current or gyre weakens seasonally. Similarly, turbulent mixing in shallow waters varies with the position of the gyre, the degree of solar heating, and the strength of the tidal effects. A broader tidal range, will increase the zones or areas of tidal mixing in shallow waters. These zones, particularly around Grand Manan Island, and off southwestern Nova Scotia, appear to serve as areas of aggregation for pre-spawning herring. Larval, juvenile, and adult herring also may follow the residual circulation pattern as they move from the Bay into the Gulf.

Herring seem to use various hydrographic structures for homing and dispersion although the exact nature of this exploitaton is unclear. Enlarging the areas of mixing may enhance or reduce herring reproduction. The relation between these Canadian herring stocks and US herring stocks and their contribution to US fisheries is unclear. Year class strength of herring in general, however, can vary greatly, suggesting that environmental factors limit reproduction and

recruitment success.

Sea scallops also exploit the region's hydrodynamic properties and illustrate well both the range in environmental factors and the fine-tuning of the biota to the system. Larval scallops spawned from the beds off Digby, N.S., travel with the residual current around the Bay of Fundy. A small, counterclockwise gyre at the mouth of the Bay carries the larvae back to the spawning grounds, where, ideally they settle. If this small gyre is weak, the larvae may be expelled into the Gulf rather than crossing back across the mouth of the Bay towards their spawning area. Water temperature controls larval development. When the Bay's circulation is closed, that is the gyre is persistent, the water temperature in the Bay increases and larval scallop development is rapid. The result is high settlement success. When the circulation is open, that is the gyre is weak and water temperatures are lower, settlement success is lower. Scallop abundances show long term variation associated with changes in these physical phenomena.

What effect Fundy tidal power will have on these phenomena remains unclear. Large areas of mixing will raise local water temperatures, but will they also alter the strength of the gyre at the mouth of the Bay? The Digby scallops are not a transboundary resource, but they illustrate the complex linkages between the biota of the Bay and Gulf with the hydrodynamic system. Further, the herring and scallop examples raise an important point. Namely, Canadian resources will be affected similarly by the changes resulting from Fundy tidal power as will US resources. Herring and scallops are fishery resources important to maritime Canada. If the Canadian environmental review process operates properly, it will evaluate the effect of Fundy tidal power on these and other resources and well as on coastal property and

structures. Indirectly, then, resources important to the US will be considered.

Neither of these illustrations answers the question of whether or not Fundy tidal power's effects will exceed the natural variation of the region, or whether the changes will be beneficial or harmful. The herring and scallop examples do suggest, however, that there is a wide range of expression of environmental factors at work in the Bay/Gulf system, and that these factors may magnify or block each other in ways we have difficulty in predicting. These interactions also suggest that an expensive research program directed at evaluating the effects of Fundy tidal power will yield little, primarily because our basic understanding, which is really only a general picture of the system's behavior, is limited. Rather, any available research funds should be directed towards understanding the mechanics of the basic system.

Finally, our review of the scientific research pertinent to assessing the effects of Fundy tidal power suggests that decisions concerning proceeding with the project should start by assuming that some damage may occur although probably only localized in extent. Given this assumption, then a cautious appraisal of the environmental benefits and costs of Fundy tidal power can proceed.

UNIVERSITY OF NEW HAMPSHIRE
DURHAM, NEW HAMPSHIRE 03824

Complex Systems Research Center
O'Kane House
(603) 862-1792

August 23, 1983

Senator George Mitchell
Committee on Environment and Public Works
Dirksen Senate Office Building, 4204
Washinton, DC 20510

Dear Senator Mitchell,

In response to your questions concerning additional research directed at predicting the transboundary effects of Fundy tidal power, our investigation suggests that relatively little would be gained either from a coastal impact study or from developing an alternate to the tidal model of Dr. David Greenberg. Our research concludes rather that the fisheries resources of the area are more vulnerable to change. Because our knowledge of the interactions between ocean circulation and fisheries productivity is so limited, it is here that additional research funds should be directed.

A six inch higher high tide under normal conditions would have little effect on coastal resources as it is well within the observed tidal variance. The effects of this increase may though be amplified as larger storm surges during large storms classified as 50 or 100 year storms. Examination of the relation between high tides and storm surges, using information collected by the U.S. Army Corps of Engineers, indicates that high tides are seldom correlated with storm surges. No reason exists to suggest that this relation will change with the presence of tidal dams in the upper Fundy. Further, the relation suggests that what are now classified as thirty, fifty and one hundred year storms will not be reclassified or become "more frequent" as has been suggested.

Dr. David Greenberg's model of the region's tidal regime is the accepted model. Development of an alternate or application of any of the numerous water quality models which might be applied to small areas off the coast of Maine will probably only add to confusion. Time series data exist for only a few tidal stations in the Gulf of Maine, a limitation Greenberg recognizes. Models of necessity emphasize several variables and minimize others as they process large amounts of data for those few variables. They cannot compensate where data are missing.

Based on these considerations, we conclude that research funds for the Gulf of Maine should be directed where they will yield better understanding and that area concerns the region's productivity.

Sincerely,

Judith Spiller
Assistant Professor

Fundy Tidal Power Project - Implications for the fisheries

Testimony of
Spencer Apollonio, Commissioner
Department of Marine Resources
State House Station #21
Augusta, Maine 04333

With the exception of the shad resource - an historically and potentially important fishery - there is little of substance that we can say with assurance on the impact of the Fundy Power Project on the fish stocks of the Gulf of Maine. It now appears that a very large percentage of all the shad of the Atlantic coast may be exposed to multiple passages, through the turbines, and therefore run a high risk of mortality as they feed each summer at the head of the Bay of Fundy. The concern for the well-being of shad appears to be well-founded; and since a number of states - including Maine - have recently made very substantial investments in the restoration of shad, it would be tragic to have those investments become meaningless.

The basis for discussion of the project's impacts on our marine resources appears to be much stronger in the areas of impacts on wetlands, circulatory and tidal patterns, basic primary productivity, and the probabilities of reduced or enhanced paralytic shellfish poisoning occurrences. These issues will be commented on by other witnesses at this hearing; they all relate to the question of the project's impact on the fisheries. Although there is more solid ground for discussion of these issues, even so there are no firm answers, as far as I know.

Even though, as I believe, we cannot predict the project's impact on the fisheries, except for shad, I would hazard a personal conviction that we can be sure, as a result of any project of this magnitude, that there most certainly will be significant, unanticipated consequences, and by law of averages those unforeseen consequences will not be beneficial. The impact of the Aswan High Dam upon the fisheries resources of the eastern Mediterranean is an example

of this kind of concern. The James Bay hydroelectric project may be another, but it is too early to be sure.

Our primary problem for considering the impact of this project on the fisheries is that the consequences are at least an order of magnitude greater than can be handled by the present capabilities of fishery science. By that I mean that the impacts of the tidal project will encompass scales of years and of hundreds of kilometers in addition to scales of days and of meters. The project will have impacts on long-term circulatory and environmental patterns as well as on daily tidal rhythms. But fishery science at the moment can not deal with this range of scales even though the fish stocks are certainly governed by the full spectrum of those phenomena, as has been clearly pointed out in a recent formal report - Fishery Ecology - by the National Academy of Sciences. The report was concerned with traditional fisheries management issues, but - most important - in the context of the environment within which fish live. Thus the principles and research needs outlined there are appropriate in attempting to understand the impact of a project such as this which may be expected to alter substantially the environment. The thrust of the NAS report was that fishery science can not be responsive to fishery management needs until the science can encompass the range of scales that I have indicated are inherent in the analysis of the Fundy project. Thus, clearly, neither is the science capable of responding to the questions posed by a project of the magnitude of Fundy.

In essence this hearing is asking questions that cannot be answered by the existing state of fishery science, just as analysis of fishery management issues is restrained by the rather primitive state of fishery science. This hearing seeks to learn what research projects should be undertaken to better define the

probable impacts on the fisheries. The point I wish to emphasize is that at this time, we lack the fundamental scientific understanding of how fish ecosystems work, and how fish species - singly and in aggregate - interact with their environment to be able to make the suggestions the hearing seeks to obtain. In short, we are suffering from a lack of basic ecosystems research.

Why is this so? Very simply, in large part it is because funding for fishery science has been rigidly compartmentalized. Scientists recognize the need, but in general the administration of funds is not responsive to the need. The agencies that support research into basic principles of ecosystems interactions "do not do fish," and the agencies responsible for fisheries are generally so pressed for immediate answers to immediate problems that they have little reserve capacity to address fundamental, long-term research problems. Thus as a result no one is developing the basic scientific concepts or methods that should be applied to the issues raised by the Fundy project. As a result of that neglect of basic ecosystem research, we have to say "we don't know; further we are not even sure how to find out."

Congress is considering the possibility of establishing the National Oceanic and Atmospheric Agency (NOAA) as an independent agency. The discussion also, I believe, involves whether the National Marine Fisheries Service (NMFS) should remain within NOAA or be transferred to a department. I would recommend that NMFS remain within NOAA. That arrangement would hold the most promise that the kind of fundamental research that is needed would in fact be undertaken; the nation's fisheries research agency would be operating within the context of the nation's systems research into oceanic and atmospheric interactions - exactly the context in which fishery science should be pursued.

Let me outline, briefly, the kind of possible interactions we don't understand. Let us assume that as a result of the Fundy project the primary

productivity of the Gulf of Maine were to increase significantly. Even so, we could not conclude that fish production would therefore increase. We simply don't know enough about the transfer of energy throughout the system to make any conclusions with much confidence. Even if in general terms we could conclude that basic energy were transferred to harvestable species, we would be very uncertain whether shellfish or finfish landings would reflect the changes, or indeed whether the additional energy might show up in "trash" - unharvestable - species.

I would like to enter into the hearing record in this context a reference to the National Academy of Sciences report* - Fisheries Ecology - as basically, our recommendation in response to the inquiry of this hearing as to the kind of work that is needed. Our answer is responsive to your inquiry but somewhat different, I suspect, from the anticipated answer. It is that if we are to be in a position to answer such questions as are posed by projects of this kind, then some basic restructuring of the way marine science is funded and administered is needed. The NAS report makes clear what that restructuring should be.

*Fisheries Ecology - some constraints that impede advances in our understanding. An ad hoc group of the Ocean Sciences Board. National Academy of Sciences, Washington, D.C., 1980. 16 pp.

Atlantic States Marine Fisheries Commission
1717 Massachusetts Avenue, N.W.
Washington, D. C. 20036

(4)

July 18, 1983

CHAIRMAN:
SPENCER APOLLONIO
DEPARTMENT OF MARINE RESOURCES
STATE HOUSE ANNEX
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EXECUTIVE DIRECTOR
IRWIN M. ALPERIN
(202) 387-5330

The Honorable George Mitchell
Subcommittee on Environmental Pollution
416 Dirksen Senate Office Bldg.
Washington, DC 20510

Dear Senator Mitchell:

I have been asked to bring to your attention a matter of grave concern to the members of the Atlantic States Marine Fisheries Commission's Interstate Fisheries Management Policy Board. This Board is comprised of administrators of the Atlantic Coast states fisheries agencies and the National Marine Fisheries Service and is dedicated to the management of interjurisdictional marine and anadromous fisheries. Recognizing the value of stocks of American shad and river herring, this organization recently authorized the development of a plan for the interstate management of these species and created a management board and scientific and statistical committee for this purpose.

Recent evidence presented to these bodies of administrators and scientists indicates the potential for a very serious problem that could impact all of the coastal stocks of American shad from Canada to Florida. This evidence, presented at the 1983 Northeast Fish and Wildlife Conference in May of this year by Dr. Michael Dadswell and associates of the Canadian Department of Fisheries and Oceans, shows that American shad from nearly every river system in eastern North America utilize the Bay of Fundy, and in particular the areas known as Minas and Cumberland Basins, as summer feeding grounds. Proposals for the development of tidal power projects within these basins are being considered by Canadian power companies and associated regulatory agencies. It is clear that these projects, when operational, will cause appreciable mortalities among these shad stocks. It has been estimated that repeated passage through turbines at these installations could cause the mutilation of as high as 90% of the shad

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present. Since it has been demonstrated that up to one third of the total Atlantic Coast shad stocks can be found in these areas during the summer feeding period, severe adverse impact can be expected from the operation of the planned facilities.

In recognition of the importance of these feeding grounds within the Bay of Fundy and the potential hazard that tidal electric generation barriers can represent to shad stocks (and other fishes such as river herring, sturgeon, and striped bass utilizing this area), I wish to express the concerns of the Interstate Fisheries Management Policy Board with these projects. We urge that full consideration be given to the extremely serious ecological damage that such projects could cause. Due consideration must be given to the anticipated economic losses to Atlantic Coast commercial fishermen, and to the full economic ramifications of these projects on the burgeoning sport fisheries these stocks now support. Other issues which should be explored fully by appropriate agencies include the effects of these tidal power projects on migratory waterfowl, and coastal impacts as far south as Boston, Massachusetts caused by permanent changes in normal tidal amplitudes.

We bring this matter to your attention in the hope that you will use whatever influence or authority you may have to assure that adequate consideration is given to this grave situation.

Sincerely,

Irwin M. Alperin

Irwin M. Alperin
Executive Director

NEW ENGLAND POWER POOL TESTIMONY

GOOD MORNING:

My name is Phillip C. Otness. I am the Executive Director of the New England Power Pool. Our offices are located at 174 Brush Hill Avenue, West Springfield, MA 01089.

I am pleased to be able to present testimony to your committee concerning the planning and capacity needs of the New England utilities. In 1971 the utilities in the six New England states formed the New England Power Pool (NEPOOL). The objectives of NEPOOL are reliability, economy, and equitable sharing of benefits. The NEPOOL system includes over 99.5% of the New England electric generation and load and is operated as a single electric system. The bulk of the remaining load is located in northern Maine and is electrically remote from our system. That load is, however, interconnected with the New Brunswick Electric Power Commission system. The NEPOOL system is interconnected with the New Brunswick system to the northeast and to the New York Power Pool to the west. Planning is well underway and contractual commitments have been executed for an interconnection with the Hydro-Quebec system scheduled for operation in 1986. There are approximately 85 individual companies represented by about 45 NEPOOL members. The member's generating needs vary in size from approximately 2 MW to as much as 4,700 MW and generating units vary in size from less than 1 MW to 864 MW. Three 1150 MW units are currently under construction.

The NEPOOL staff provides the following services for the system and all of its members:

- Long range (20 years) forecasting of electrical peak loads and energy,
- Generation and transmission planning guidelines for reliable and economic system expansion,
- Minute to minute operation and dispatch of all generation and major transmission,
- Accurate billing for all pool transactions.

The concept of NEPOOL is to operate all facilities without regard to ownership, thereby assuring the lowest total cost for New England consumers. In 1982 NEPOOL savings reached an all time high of $62,000,000 of which $17,000,000 was generated from transactions with New Brunswick Electric Power Commission and the New York Power Pool. The 3,735,000 MWh of energy purchased from these neighboring pools displaced about 6,350,000 barrels of oil in New England.

The highest peak load that New England has experienced was 15,702 MW which occurred on January 11, 1982 while the highest summer peak was 15,396 MW occurring on July 19, 1982. Over the 1963-1972 period, the New England average compound load growth was 7.5% and had this continued, we would have experienced the 15,700 MW peak in 1974. The actual average compound load growth over the 1973 to 1982 period was about 1.9%. This loss of the equivalent of 10 years load growth is an illustration of the effects of the oil embargo, conservation, and the resulting economic

recession during the last decade which is continuing, to some extent, today.

Price induced conservation by residential, commercial, and industrial customers since 1974 has significantly impacted load growth and eliminated the need to install approximately 10,000 MW of generating capacity. Load management by the NEPOOL companies has also drastically affected the load level. Reflected in our current load forecast is more than 1000 MW of load management by the year 2000.

The current NEPOOL forecast for electric load growth through the year 2000 calls for an average annual compound growth of 1.8% for winter and summer peak loads, and 2.2% for energy. Based on NEPOOL's present schedule of additions, purchases, and retirements, it is expected that adequate reserves, to serve the forecasted load and provide for unforeseen contingencies, will be available through about 1995/1996 as shown on Table 1. Beyond that year we project that we will require additional resources of about 2000 MW to adequately meet needs through the end of this century.

The energy forecast and source of supply by fuel types is shown on Table II. No major generation is being actively pursued for completion in the 1990s although several potential projects are under consideration.

Our goal in New England for the last decade has been to reduce dependence on foreign oil. In 1973, 65.5% of the electricity was generated by oil. By 1980, this was reduced to 55.6%. In 1982, this was even further reduced to 39.8%. Exhibits 1-3 dramatically illustrates that oil generation is projected to drop to a low of about 15% in 1990 and subsequently increases to about 28% in the year 2000. Therefore we

must have additional resources in the 1990s and planning must start soon if we are to continue to meet this objective.

The following NEPOOL units are under construction: Seabrook nuclear units #1and #2, and Millstone nuclear unit #3. I can't emphasize enough, that they must be finished along with 1600 MW of future coal conversion if we are to achieve the reduction in oil consumption highlighted in the exhibits.

I mentioned earlier our plans to complete an interconnection with Hydro-Quebec. Phase I negotiations were satisfactorily completed in March of 1983 providing for the NEPOOL purchase of 33,000,000 MWh of electricity during an 11-year period from September 1986 to August 1997. Agreement was also reached on the construction and use of a 690 MW direct current interconnection between the two power systems. Since March, negotiating committees from NEPOOL and Hydro-Quebec have been meeting to explore the cost, benefits, and timing of upgrading these facilities to an approximate capacity of 2000 MW. Hydro-Quebec has forecasted considerable energy surpluses available in the early 1990s. Hydro-Quebec has not offered capacity beyond the mid-1990s, due to the reduction of their construction program and the uncertainties of load growth, construction cost, inflation, etc. NEPOOL has forecasted that it needs firm capacity after the mid-1990s. NEPOOL also desires to displace its oil consumption to the maximum extent it is economical.

We are also exploring other possible purchases which have been recently offered such as capacity from New Brunswick Pt. Lepreau unit II (630 MW) in the early 1990s, as well as, joint participation in a coal unit that has been proposed within the New York Power Pool. New England

has several potential coal units of its own, including Sears Island and Canal #3 projects both of which could be operational by 1995.

NEPOOL will examine every possible alternative for meeting expected capacity needs during the 1990s. Alternatives include but are not limited to - biomass, co-generation, fuel cells, small hydro, trash burning, solar, wind, and advanced coal technology. These alternatives could possibly contribute as much as 1500 MW of capacity to the New England system by the year 2000. They will be evaluated on there own merits but must compete economically against th other alternatives that are available and have been cited above.

There exists in the NEPOOL system about 200 MW of deactivated oil-fired capacity that could be returned to service if needed, and the existing NEPOOL generating unit retirement plans include an additional 1900 MW of oil-fired generation which could be continued if necessary. However, many units will be 50 years old by the year 2000 having long exceeded their expected useful and efficient service lives.

We believe it is important to explore all opportunities for power development especially in the northeast area where we have been overly dependent on fossil fuel. In planning for the future, we must seek both additional resources within our own system and strong transmission interconnections with other systems. Only through strong interconnections can we take advantage of regional diversities including hydro potential, weather, tides, daylight, etc. A series of such interconnections where large movements of power can take place in a reliable manner over great distances could result in substantial savings to our customers.

We encourage the committee's further study of the environmental effects of Canadian tidal power projects. We must do our homework now if we are to make the wisest choice of resources for the future.

I hope this information will be of assistance to the Senate Committee. Again, I thank you for your time and I appreciate the opportunity to appear before you today.

TABLE 1

ESTIMATE OF NEW ENGLAND CAPACITY NEEDS TO 2000

		1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01
(1) N.E. Capacity	(MW)	24934	25019	24683	24553	24636	24175	24538	24490	24161	23805	23805	23805
(2) Peak Load	(MW)	17636	18072	18353	19025	19428	19802	20128	20408	20657	20904	21199	21483
Installed Reserve	(MW)	7298	6947	6330	5528	5008	4373	4410	4082	3484	2901	2606	2322
	(%)	41.4	38.4	33.0	29.1	25.8	22.1	21.9	20.0	16.9	13.9	12.3	10.8
(3) Peak Load Reduction Required to Meet Criterion	(MW)	—	—	—	—	—	—	—	299	903	1428	1436	1818

NOTES

(1) Source for Capability is from 4/1/83 New England Forecast Report of Capacity, Energy, Loads and Transmission 1983-1998 including Seabrook 1 (12/31/84), Seabrook 2 (7/31/86), Millstone 3 (5/1/86), and Seare Island (11/1/95) Pool Planned Units, estimated deratings from coal conversions but excluding deactivated units.

(2) The peak load forecast reflects annual estimates of participants load management efforts. These amount to 316 MW and 943 MW in 1983/94 and 1998/99, respectively.

(3) Peak load reduction required to meet the reliability criterion with the capability shown on first line (See Note 1)

NEPOOL
7/22/83

TABLE II

NEW ENGLAND ENERGY AND SUPPLY STATUS WITHOUT UNCOMMITTED SOURCES

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Energy Forecast (GWh)	101680	104580	107460	109980	112350	114570	116560	118370	120140	121900	123620
Less Estimated Supply											
(1) Nuclear (GWh)	48782	49736	49922	50189	49983	50085	50106	50185	49932	50230	49884
(2) Coal (GWh)	27565	27535	27175	27468	27173	27729	29887	29684	29760	30393	30248
Hydro	5088	5088	5088	5088	5088	5088	5088	5088	5088	5088	5088
Net Pump Storage Gen.(GWh)	-477	-462	-398	-380	-368	-419	-417	-410	-458	-504	-575
Wood	354	371	417	490	517	515	516	551	556	546	569
Solid Waste	25	24	24	24	24	24	24	24	24	24	24
Purchases:											
(3) Hydro-Quebec (GWh)	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
(4) Other (GWh)	2409	2130	1278	1220	1220	1220	1220	1220	1225	1259	1259
Oil Generation (%)	14.7	16.4	19.5	20.8	22.9	23.9	23.3	24.5	25.8	26.1	27.6
(GWh)	14934	17158	20954	22881	25713	27328	27136	29028	31013	31848	34101
(5) Deficiency (GWh)	—	—	—	—	—	—	—	—	—	16	22

NOTES:

(1) Includes existing units and planned additions of: Seabrook 1 (12/31/84), Seabrook 2 (7/31/87), and Millstone 3 (5/1/86).

(2) Includes existing units, conversions and planned conversions to coal firing and Sears Island (11/1/95).

(3) Existing target energy contract with Hydro-Quebec assumed extended beyond 1997.

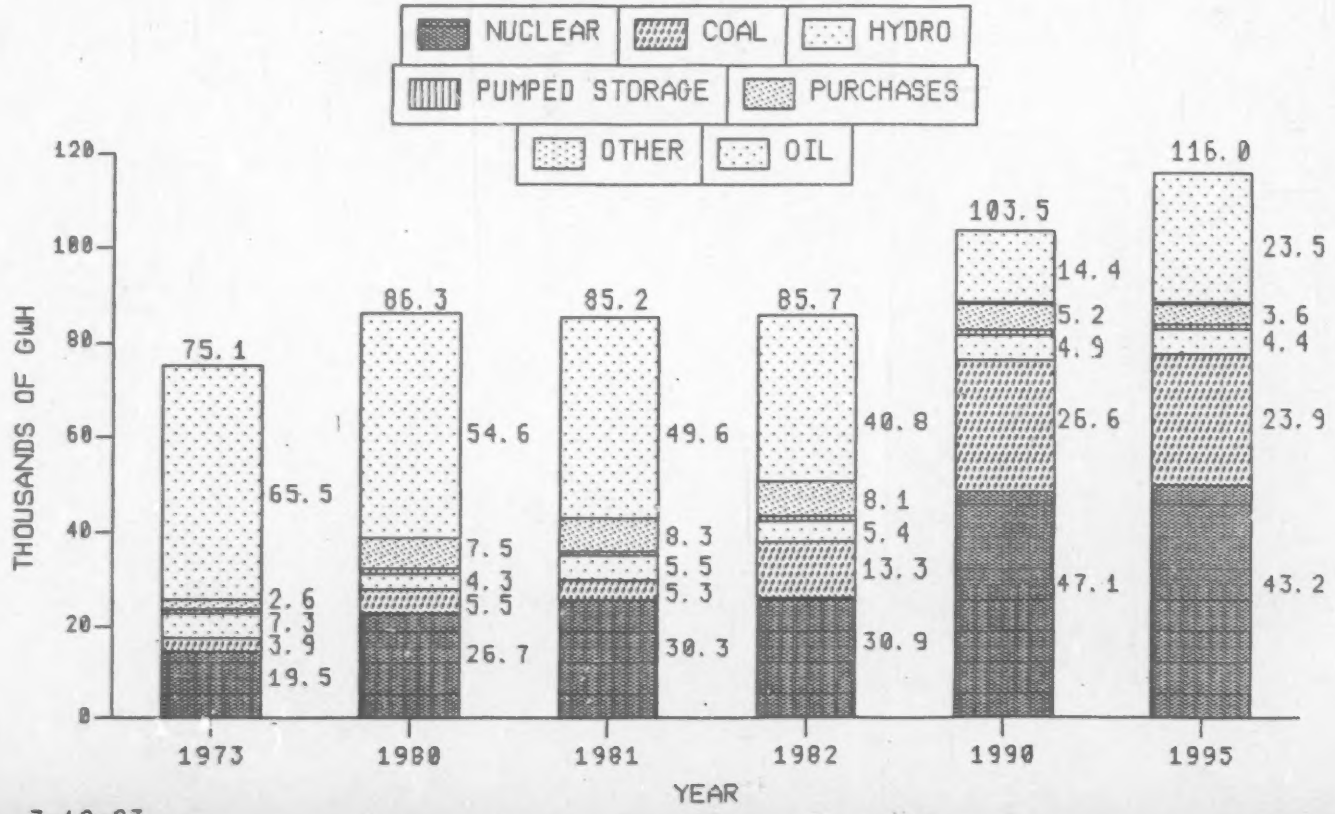
(4) Other existing contracts such as PASNY power assumed extended.

(5) System energy deficiency.

NEPOOL
7/22/83

Exhibit 1

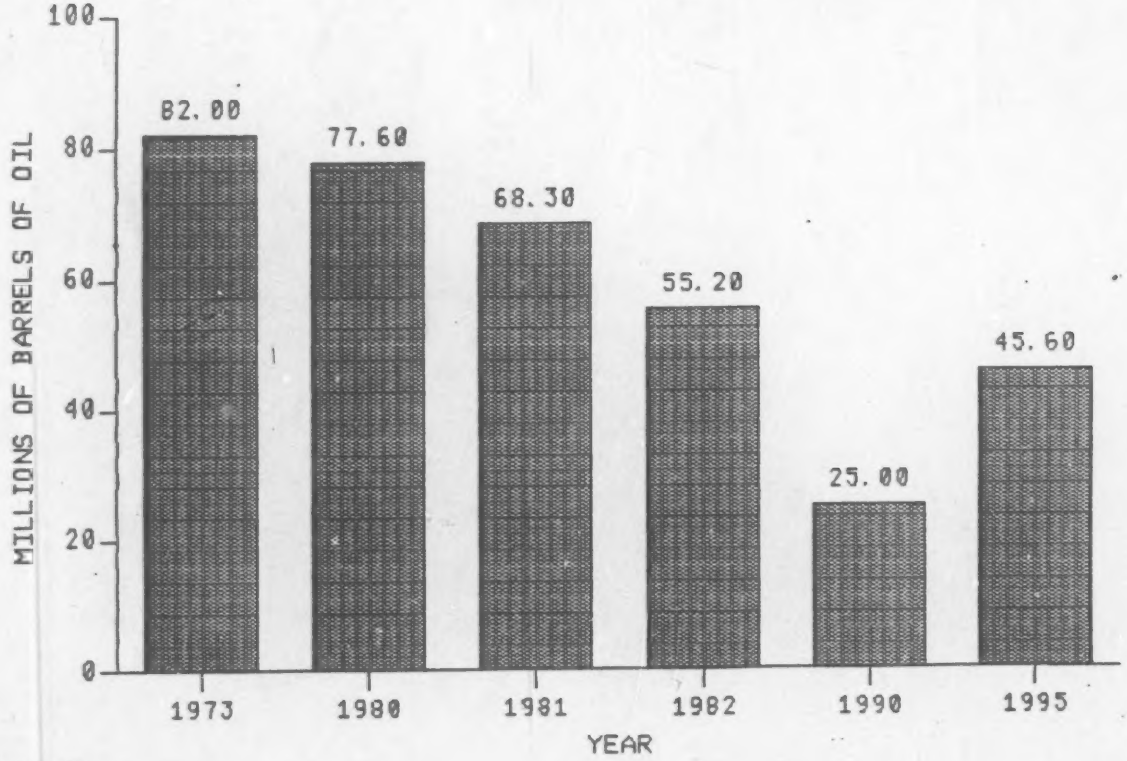
NEW ENGLAND ENERGY REQUIREMENTS BY FUEL SOURCE
PAST AND PROJECTED



7-19-83

Exhibit 2

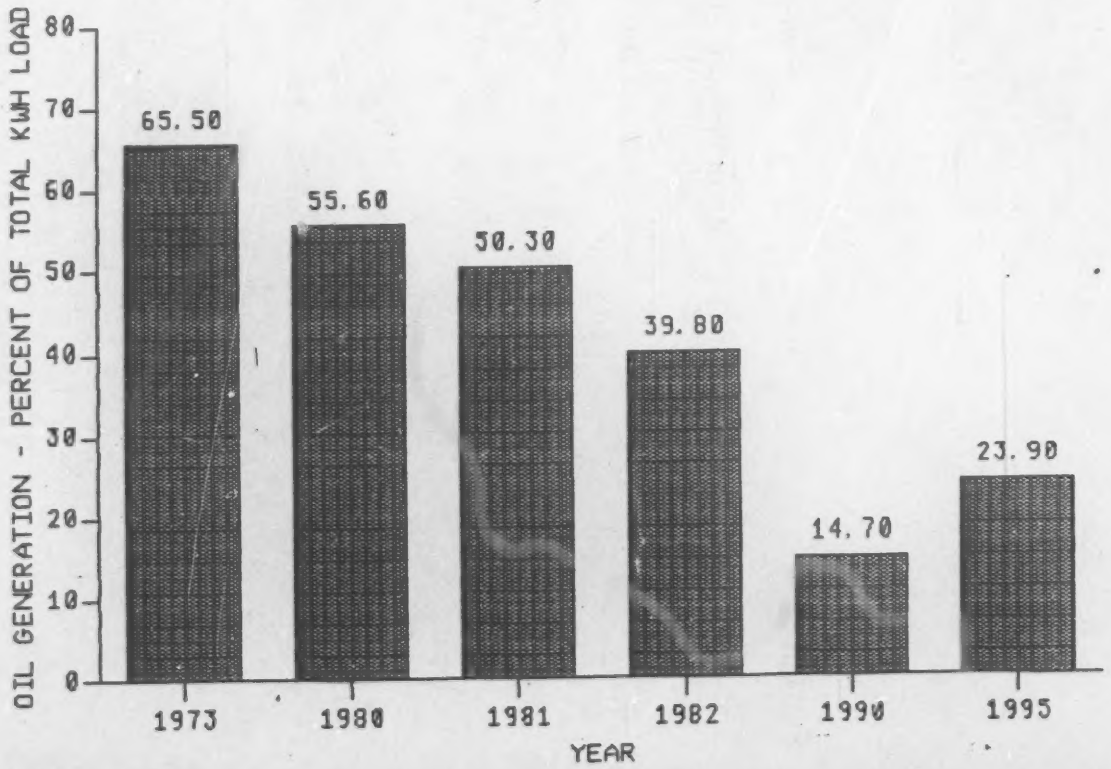
NEW ENGLAND OIL DEPENDENCY
PAST AND PROJECTED



7-19-83

Exhibit 3

NEW ENGLAND OIL DEPENDENCY
PAST AND PROJECTED



7-19-83

TESTIMONY BY MARK ISHKANIAN
ON BEHALF OF THE
NATURAL RESOURCES COUNCIL OF MAINE
BEFORE THE
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
OF THE UNITED STATES SENATE

JULY 25, 1983

I WOULD LIKE TO THANK SENATOR MITCHELL AND SENATOR CHAFEE FOR THIS OPPORTUNITY TO EXPRESS THE VIEWPOINTS OF THE NATURAL RESOURCES COUNCIL OF MAINE, A CITIZENS CONSERVATION ORGANIZATION.

IT'S BEEN SUGGESTED TO ME ON A NUMBER OF OCCASIONS THAT THE FUNDY TIDAL PROJECT IS CANADA'S MEANS OF SEEKING REVENGE UPON THE UNITED STATES FOR THE MILLIONS OF TONS OF SULFUR DIOXIDE WE DUMP ON EASTERN CANADA EACH YEAR IN THE FORM OF ACID RAIN. WHILE MAINE, AS A VICTIM OF ACID RAIN POLLUTION ITSELF, CAN CERTAINLY SYMPATHIZE WITH THE CANADIAN VIEWPOINT, WE FEEL THAT THEIR EFFORTS ARE SOMEWHAT MISDIRECTED. INSTEAD OF FLOODING THE MAINE COASTLINE, THEY SHOULD TRY TO RAISE THE LEVEL OF LAKE ERIE ENOUGH TO PUT PORTIONS OF THE MIDWEST UNDER WATER. THEN WE MIGHT GET SOMEWHERE!

ON A MORE SERIOUS NOTE -

THE NATURAL RESOURCES COUNCIL HAS A STRONG INTEREST IN THE USE OF TIDAL POWER AS AN ALTERNATIVE ENERGY SOURCE TO REDUCE OUR DEPENDENCE ON FOSSIL FUELS AND NUCLEAR POWER. WE HAVE CLOSELY FOLLOWED DEVELOPMENTS OF THE COBSCOOK BAY AND HALF MOON COVE TIDAL PROJECTS AND MAINTAIN AN OPEN MIND PENDING THE AVAILABILITY OF DETAILED ENVIRONMENTAL STUDIES. BUT THE MAGNITUDE OF THE MINAS BASIN PROJECT AND THE TREMENDOUS ENVIRONMENTAL UNCERTAINTIES SURROUNDING IT CANNOT HELP BUT ALARM CONSERVATION INTERESTS. AT STAKE ARE MAINE'S RICH COASTAL AND MARINE RESOURCES - A UNIQUE PART OF OUR NATURAL HERITAGE AND AN ESSENTIAL COMPONENT OF OUR STATE'S ECONOMY AND A WAY OF LIFE.

THE GULF OF MAINE IS A VAST, COMPLEX, AND POORLY UNDERSTOOD ECOSYSTEM. THE EXPERTS HERE TODAY HAVE ONLY BEEN ABLE TO HINT AT THE ENVIRONMENTAL IMPLICATIONS OF THE FUNDY TIDAL PROJECT. THEY READILY ADMIT THE DIFFICULTY OF PREDICTING WITH ANY ACCURACY THE FULL IMPACTS OF THE PROJECT. IT IS

AN UNFORTUNATE DILEMMA OF THESE TIMES, THAT OUR ABILITY TO MANIPULATE THE WORLD ENVIRONMENT IS PROGRESSING AT A FAR MORE RAPID RATE THAN OUR ABILITY TO UNDERSTAND THE IMPLICATIONS OF THESE ACTIONS. ACID RAIN, HAZARDOUS WASTES, AND TOXIC PESTICIDES ARE BUT A FEW OF YESTERDAY'S MISTAKES THAT WE ARE PAYING FOR TODAY.

BUT EVEN WHEN WE LOOK AT THE FEW IMPACTS OF THE MINAS BASIN PROJECT THAT WE CAN PREDICT TODAY WITH SOME CERTAINTY, THE COUNCIL FINDS COMPELLING ARGUMENTS AGAINST ITS CONSTRUCTION.

CANADA'S DR. MICHAEL DODSWELL HAS DISCOVERED THAT A MAJOR PORTION OF THE EAST COAST'S AMERICAN SHAD POPULATION CONVERGES AT THE HEAD OF THE BAY OF FUNDY FOR A FEW WEEKS EACH SUMMER TO FEED. PRESUMABLY, THE SHAD WOULD TRAVEL THROUGH THE DAM'S SLUICE GATES TO THEIR FEEDING GROUNDS IN COBEQUID BAY ONLY TO BE SWEPT THROUGH THE POWERFUL TURBINES EVERY SIX HOURS. IT'S BEEN ESTIMATED THAT A 10 - 40 PERCENT MORTALITY RATE WOULD OCCUR OF SHAD PULLED THROUGH THE TURBINES. BARRING THE DEVELOPMENT OF EFFECTIVE MITIGATIVE MEASURES,

IT'S ESTIMATED THAT SOME 40 - 70 PERCENT OF THE EAST COAST SHAD POPULATION COULD BE LOST OVER A TEN YEAR PERIOD.

IN HIS WORK, DR. DODSWELL ALSO INDICATED THAT TREMENDOUS NUMBERS OF BLUEBACKED HERRING AND ALEWIFE USE THE MINAS BASIN/COBEQUID BAY REGION ALONG WITH THE SHAD AND ONE CAN ONLY ASSUME THAT THEY TOO WILL SUFFER A SIMILAR FATE IN THE TURBINES. THE ORIGINS OF THESE SPECIES AND TO WHAT EXTENT THE GULF OF MAINE FISHERY WOULD BE IMPACTED BY THE TIDAL PROJECT ARE IMPORTANT QUESTIONS CALLING FOR FUTURE STUDY.

A SECOND KNOWN IMPACT OF THE FUNDY TIDAL POWER PROJECT WHICH IS OF GREAT CONCERN TO THE COUNCIL IS THE INUNDATION AND ACCELERATED EROSION OF MAINE'S SAND BEACHES AND DUNES.

FOR CLOSE TO A DECADE, NRCM HAS BEEN A STRONG AND CONSISTENT VOICE ADVOCATING THE WISE MANAGEMENT OF OUR FRAGILE SAND DUNE SYSTEMS. WE HAVE BEEN INVOLVED IN DOZENS OF SAND DUNE CASES BEFORE THE DEPARTMENT OF ENVIRONMENTAL PROTECTION. JUST A FEW WEEKS AGO, THE STATE OF MAINE TOOK A BIG STEP FORWARD BY IMPLEMENTING NEW REGULATIONS WHICH WILL IMPROVE

PROTECTION OF OUR SAND BEACHES FROM INAPPROPRIATE DEVELOPMENT.

ALL THE GAINS OF THE PAST YEARS ARE OVERSHADOWED BY THE POTENTIAL CONSEQUENCES OF THE MINAS BASIN PROJECT. THE BIGELOW LAB STUDY ESTIMATES THAT SOME BEACHES IN SOUTHERN MAINE WOULD RETREAT AS MUCH AS 60 FEET AND THAT SEVERE STORMS CAUSING EXTENSIVE BEACH EROSION WOULD MORE THAN DOUBLE IN FREQUENCY.

TO UNDERSTAND THE FULL IMPLICATIONS OF THESE IMPACTS ONE MUST FIRST UNDERSTAND OUR SAND BEACHES TODAY. THESE BEACHES, WHILE COMPRISING ONLY A SMALL FRACTION OF THE STATE'S OVERALL COASTLINE, ARE A MAJOR RECREATIONAL, ECONOMIC AND ECOLOGICAL RESOURCE. EVEN NOW, OUR 37 MILES OF SAND BEACHES ARE A HIGHLY STRESSED ECOSYSTEM. OVER 60 PERCENT OF OUR BEACHES ARE DEVELOPED AND MUCH OF THIS DEVELOPMENT HAS OCCURRED IN A MANNER WHICH HAS ACCELERATED BEACH EROSION. EACH SUMMER MILLIONS OF PEOPLE DESCEND UPON MAINE'S BEACHES, TAKING THEIR TOLL ON VITALLY IMPORTANT DUNE VEGETATION AND CRITICAL WILDLIFE HABITAT FOR SUCH RARE BIRD SPECIES AS THE LEAST TERN AND PIPING PLOVER.

INCREASED TIDAL LEVELS AND STORM SURGES CREATED BY THE FUNDY PROJECT WILL FUNDAMENTALLY CHANGE THE CHARACTER OF OUR SOUTHERN COASTLINE, SWALLOWING UP LARGE SECTIONS OF BEACH (TO SAY NOTHING OF THE HOUSES BUILT UPON THEM). THIS, IN TURN, WILL CONCENTRATE HUMAN PRESSURES ON THE REMAINING SAND BEACHES AND DUNES LEADING TO INCREASED DESTRUCTION OF THESE FRAGILE AREAS.

FOR YEARS WE HAVE ENCROACHED UPON THESE FRAGILE SAND SYSTEMS FROM THE LAND. IF WE NOW ENCROACH UPON THEM FROM THE SEA WE MAY FIND THAT THERE WILL BE LITTLE LEFT TO ENJOY.

BUT WHAT ALARMS THE COUNCIL MOST ABOUT THIS PROJECT IS THE MULTITUDE OF UNANSWERED QUESTIONS AND THE QUESTIONS WHICH HAVEN'T EVEN BEEN THOUGHT OF YET. SHIFTS IN CIRCULATION PATTERNS, A DECREASE IN SURFACE WATER TEMPERATURE, SALT MARSH FLOODING, CLIMATIC CHANGES, INCREASED RED TIDE OCCURRENTS AND FLUCTUATION IN PRIMARY PRODUCTIVITY ARE ALL AREAS OF GREAT UNCERTAINTY. HOW THESE CHANGES TOGETHER WILL AFFECT THE DISTRIBUTION AND ABUNDANCE OF OUR FISHERIES IS OF THE

UTMOST IMPORTANCE, YET APPEARS TO BE BEYOND THE TOOLS OF MODERN DAY MARINE SCIENCE.

ONLY A FEW PIECES OF THE FUNDY TIDAL POWER PUZZLE ARE IN PLACE - BUT ALREADY A PICTURE OF UNPRECEDENTED ENVIRONMENTAL AND ECONOMIC DISRUPTION OF OUR OCEAN AND COAST IS APPEARING. UNDERSTANDING THAT MANY OF THE PREDICTED IMPACTS OF THE PROJECT ARE BASED ON DR. GREENBERG'S MODEL, THE NATURAL RESOURCES COUNCIL RECOMMENDS FURTHER RESEARCH TO SUBSTANTIATE AND REFINE DR. GREENBERG'S WORK. ADDITIONALLY, WE RECOMMEND THAT CANADIANS EXPLORE OTHER SMALLER SCALE TIDAL POWER OPTIONS WHOSE IMPACTS WE WOULD EXPECT TO BE OF A SMALLER MAGNITUDE AND LESS FAR-REACHING. WITH OUR EXPERIENCE IN TIDAL POWER PRODUCTION STILL IN ITS INFANT STAGE, IT SEEMS PRUDENT TO DEVELOP SEVERAL SMALL STATIONS AND EVALUATE THEIR IMPACT PRIOR TO CONSIDERATION OF SUCH A GARGUANTUAN AFFAIR AS THE MINAS BASIN PROJECT.

THANK YOU AGAIN FOR THIS OPPORTUNITY TO PRESENT THE NATURAL RESOURCES COUNCIL'S VIEWS ON THE FUNDY TIDAL PROJECT.

Statement of
Colonel Carl B. Sciple Division Engineer
New England Division, Corps of Engineers

Before the Committee on Environment and Public Works
United States Senate
at the State House, Augusta, Maine

July 25, 1983

Senator Mitchell, I am Carl Sciple, Division Engineer of the New England Division Corps of Engineers. It is a pleasure to appear before your committee today to discuss the items on the Bay of Fundy. I have with me today Mr. Joseph Ignazio, Chief of my Planning Division who is familiar with the ongoing activities in the Bay of Fundy and the Gulf of Maine.

I have been asked by the Chief of Engineers, Lt. General Joseph Bratton to appear before you to represent the Corps of Engineers and to provide information that was requested by the Chairman of your Committee. Senator Stafford requested the Corps provide a discussion of studies that have been conducted by the Corps relating to tidal power development in the Bay of Fundy and the Gulf of Maine together with an outline of work still to be accomplished by the Corps. The Chairman also requested a discussion of studies that should reasonably be undertaken together with the discussion of the studies that would be within the capability of the Corps to analyze the environmental impact of the proposed Canadian Bay of Fundy project on the United States.

I would like to first discuss the Corps' activities in the Bay of Fundy in the Gulf of Maine. The idea of harnessing tides for electricity

in the Passamaquoddy and Cobscook Bays was first conceived by engineer Dexter Cooper in the early 1920's and later supported by President Franklin Roosevelt. Construction was initiated in 1935 but never completed. Had the initial tidal power project been completed, it would now be producing energy at a cost of less than 10 mills per kilowatt hour. In 1956 the Governments of the United States and Canada requested that the International Joint Commission investigate the possibility of a cooperative international power project in Passamaquoddy Bay. The Corps of Engineers as consultant to the IJC undertook the study, submitting its findings to the International Passamaquoddy Engineering Board. In 1961, the Board concluded that a tidal power project would not be economically justified.

The project was later reviewed in the early 1960's to determine if it was feasible based upon more advanced engineering technology and changed economic conditions. This effort culminated in a 1965 report which concluded that the tidal project remained not economically justified. In 1976, the Congress directed the Corps to restudy the Passamaquoddy tidal project to determine its economic feasibility in light of rapidly escalating oil prices. However at that time the Canadian Government chose not to participate in development of an international project at Passamaquoddy Bay as their attention was being focused on developing their own tidal projects at the head of the Bay of Fundy, where tides range up to 52 feet — a more favorable differential compared to up to 25 feet at Passamaquoddy Bay. With the withdrawal of the Canadians from the international studies the Corps proceeded with what has been called an "All American" tidal plan at Cobscook Bay, Maine.

The Cobscook study area covers approximately 39 square miles that could be impacted at high tide with 400 square miles of drainage area. Several alternatives were evaluated involving projects for tidal power potential. Alternatives ranged from 5 to 450 megawatts of installed capacity that could produce between 16 and 790 million kilowatt hours of electricity annually.

The preliminary studies determined that tidal power in Cobscook Bay was economically feasible and that the energy from an intermittent single pool tidal power project could be absorbed and utilized in New England. The evaluation of potential environmental impact of this project, however, has not yet been accomplished. This effort will require establishing social and environmental base line studies and evaluating the impact of alternative projects. Marketing and transmission studies to determine financial feasibility also need to be pursued.

By way of just general comparison, as I noted earlier, the largest of the alternatives that the Corps has evaluated at Cobscook Bay would generate 790 million kilowatt hours annually. The proposed Canadian development in Minas Basin is reported to be able to produce 12 billion kilowatt hours.

That brings us to the second question that I was asked to respond to, namely, the analysis of the environmental impacts of the proposed Canadian Bay of Fundy project on the United States.

The proposed Canadian development in the Minas Basin could create problems through an increase in tidal range extending from Maine southward to Cape Cod, Massachusetts. It has been reported that this change in the tidal range could vary from 6 to 18 inches. If this is true, the raising of mean high water levels could seriously impact on the many manmade structures along the coastal region. It also has the possibility of destroying the fragile natural ecosystems recently protected by the Congress when they passed the Barrier Island Bill. There could be a physical impact on navigation projects if mean low water levels are lowered. For instance, with the difference of 12 inches, commercial vessels which fully utilize the available depth would thereafter need to enter the harbor lightloaded or wait for higher tides - resulting in a decrease in efficiency and an increase in cost to business and consumer alike. There are approximately 125 projects of the New England Division of the Corps which could be affected by these tidal changes. In addition, the states, local and private interests have also constructed many other channels and facilities which could be affected. Of grave concern would be the impact to public and private shorefront development. Massive erosion could occur that would affect homes, cottages, hotels, and many miles of beaches.

In order to evaluate these problems, studies that should be undertaken at this time relating to the Bay of Fundy tidal power development should initially concern themselves with the verification of the amount of tidal surges that can be expected to occur and what natural and manmade resources could be threatened by such shifts. This means a

re-evaluation of the previous mathematical model which was first used to predict tidal stage changes. The Corps is a leader in tidal hydraulics and has outstanding expertise in sophisticated state of the art mathematical modelling techniques and could provide assistance in this area.

Upon verification of the analytical approach used in the previous model, attention would then shift to determining the necessary environmental baseline requirement needed in the mathematical model. Information would have to be drawn not only from the Corps and other State and local laboratories but the National Marine Fisheries, Fish and Wildlife Service and possibly EPA. This effort would have to be coordinated with the Environmental Offices of the Maritime Provinces to make available any data or inventories that may have already been completed or underway in the Maritime Provinces.

Both New England and Canada would benefit from an examination of environmental impacts on such issues as red tide and the anadromous fish runs which currently traverse the Bay of Fundy. If the tidal surge of 6 to 18 inches is verified, the Corps' concern would be its impact on the Federal investment on the 125 Federal coastal projects. In addition the New England States would also be concerned with the impact on their investments in the area. Study efforts would be made to determine what modifications would be made to offset the impact of the tidal surge - or changes in mean low water.

I believe that the Corps working with the IJC could coordinate an effort by all State and other Federal agencies and the Maritime Provinces to develop studies that would assess the environmental, physical and economic impact of such a project.

Mr. Chairman, in summary, I suggest a two-phase study would be a reasonable approach to a more finite determination of the proposed project's effect. The first phase should focus on the tidal regimen using current state of the art technology in modeling and to then identify the degree of effort required to assess the impacts upon the natural and manmade resources along the affected coastline. If Phase 1 studies indicate there is a significant change in the tidal range then Phase 2 studies should proceed. The Phase 2 studies should determine the environmental, social, and economic impacts and what measures, if any, can be taken to offset these impacts.

Mr. Chairman that concludes my statement - I would be glad to respond to any questions that you may have. Thank you.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02254

REPLY TO ATTENTION OF

August 19, 1983

Planning Division

Honorable George J. Mitchell
United States Senate
Washington, DC 20510

Dear Senator Mitchell:

On July 25, 1983, during the hearing held in Augusta, Maine by your Senate Committee on Environment and Public Works, you requested that I provide a cost estimate for the Corps to accomplish studies to verify the potential impacts of Canadian tidal power projects in the Bay of Fundy which reportedly could increase the mean tide range up to 11 inches in Boston and possibly higher changes along the Maine coast.

This Letter Report submits known information on the work of Doctor Greenberg as well as our best estimate of costs to accomplish initial studies of this far reaching and important project.

Phase 1 studies would focus on verifying project changes on the tidal range using current state-of-the-art technology in mathematical modelling. It would then identify the degree of effort required to assess the impacts. This would be accomplished by first determining tidal variations with a project, identifying the coastal and inland areas to be affected and inventorying the resources likely to be affected along with their potential impacts. If significant tidal variations are verified then this information would provide a basis for determining the scope and cost of Phase 2 studies which would determine the environmental, social, economic, and institutional impacts and what measures, if any, could be taken to offset adverse impacts. This latter phase could be extensive in time and dollars needed to acquire answers critical to appropriate decisions regarding these projects.

Phase 1 studies would be accomplished in two years at a cost of $1,100,000. The funding needed is $480,000 the first year and the balance of $620,000 the second year. The Corps Waterways Experiment Station (WES) would accomplish the initial modelling for verification of tidal variations. They would also determine the scope and cost of Phase 2 mathematical and physical hydrodynamic modelling. The New England Division would manage the Phase 1 effort. It would identify the coastal and inland areas affected, and specifically the Federal projects likely to be impacted, and coordinate efforts by other agencies to inventory a wide variety of resources. It would then assist in preparation of the Phase 2 scope of work and costs.

The following information is provided to strengthen your hearing record and describes an earlier review of Corps concerns regarding Doctor Greenberg's Thesis while providing basis for Phase 1 efforts.

(1) A brief review of Dr. Greenberg's Thesis accomplished by the Corps Waterways Experiment Station (WES) provided a laboratory evaluation of the subject paper, and sets the stage for further study, which will assess available laboratory expertise, and the capability to execute additional investigations needed to reliably quantify the oceanographic, coastal, water quality, and environmental impact of the proposed Bay of Fundy Tidal Power Projects.

(2) Dr. Greenberg's Thesis describes a vertically integrated numerical tidal model set up to test the effects of alternative tidal barriers installed in the upper reaches of the Bay of Fundy which traverse into the Gulf of Maine and out to the Northwest Atlantic Ocean. The barrier models take advantage of the extraordinary high tides in the bay for a potential power station.

(3) Earlier modelling efforts accomplished by others have indicated that tidal barriers in the bay probably influence a large area including the Gulf of Maine, and consequently, the Gulf of Maine, continental shelf and Bay of Fundy were incorporated into the Greenberg model as a combined system.

(4) To make the model feasible in terms of computer time and memory, a method was developed (Dr. Greenberg's Thesis) to incorporate finite difference grids of differing sizes in different regions. This allowed fine resolution to be achieved in the area of primary interest, i.e., Bay of Fundy, while coarser resolution was provided in the rest of the model domain (Gulf of Maine and continental shelf). Flooding and non-linear advection were accounted for in the model.

(5) In the mathematical expression of tidal motion there are scores of harmonic elements, or constituents, of the total tide. In the United States, 37 constituents are found to be adequate for describing the tide at most tide stations (Schureman, 1941). The symbol used to represent the rotation of the Earth with respect to the Moon is referred to as M2 and is the largest single component of the semidiurnal tide (two highs each lunar day). It generally accounts for about 70% of the total tidal amplitude. The spatially varying amplitude and phase of the M2 tidal constituent were input along the seaward deep water boundary of the model. They were adjusted in the absence of barriers until approximate model calibration was achieved. The model was then run using the same adjusted M2 boundary tide for four different barrier schemes which simulated permeable and impermeable barriers for different types of power generation stations.

(6) Although the numerical model described in the Greenberg Thesis appears to be a good "first cut" at ascertaining the hydrodynamic effects of the tidal power barrier schemes, the Corps has reservations about some of the model results and details.

(7) The numerical model was calibrated but not verified. Therefore additional tide measurements are necessary for a more complete model calibration and verification. There must be sufficient confidence in the model results in order to use them as a basis for the important decisions required concerning effects of potential project impacts which are considered positive and negative.

(8) The bed elevations used in each grid cell were not given. Therefore it was impossible to determine how realistically the bathymetry was as represented in parts of the model. For example, it was not clear how well the bathymetry near the U.S. coastline was represented.

(9) The rationale for the barrier-weir coefficients provided to Dr. Greenberg by Mr. Wilson was incomplete with no explanation of how Mr. Wilson arrived at his coefficient values.

(10) The Gulf of Maine-Bay of Fundy response appears sensitive to the location of the seaward boundary, the depth distribution along this boundary, and the M2 amplitude and phase distribution along the boundary. A more detailed sensitivity study is necessary to quantify how the boundary location and depth distribution, and the M2 amplitude and its phase distribution affect tidal response of the system.

(11) The Gulf-Bay combined system is nearly resonant with the M2 tide. It is well known that even small non-linear interactions can significantly alter the response of a system so near resonance. It is probable that tidal constituents other than M2 will interact non-linearly with the M2 constituent. Results of Greenberg's Thesis do not address this crucial question. A more complete and reliable representation of the tidal constituents, namely, amplitude and phase of sufficient constituents to comprise at least 96% of the total tidal energy on the seaward boundary is necessary. This would allow us to reliably quantify the actual response of this complex system to the real tidal input, rather than only the response of the system to the M2 constituent which comprises only about 70% of the total tidal amplitude.

(12) Stratification effects, namely, three dimension effects including modification of the temperature, salinity, and other important physical, chemical and biological constituent

distributions in the Gulf of Maine-Bay of Fundy were not studied. Potential modification of these oceanographic parameters must be quantified to ascertain the extent of environmental impacts upon marine fisheries and shellfish industries of the entire area.

(13) Combined effects of winds and tides were not studied using the actual prototype bathymetry. It is conceivable that a tide and strong northeaster, combined with a given barrier configuration, could "significantly" modify the hydrodynamics from what it would be in the absence of the barrier. This modification has the potential for even more serious impacts to water levels in United States waters and specifically along the entire New England coast.

(14) Because of the proposed barrier placement Boston has a high predicted percent change in tidal elevation. This result is somewhat suspicious since Boston is the most distant city within the study area and away from the barrier. However, such an anomalous water level behavior could conceivably be due to the near resonance of the Gulf of Maine-Bay of Fundy system. It also could be due to the lack of spatial resolution near Boston, or to anomalous boundary effects of the numerical model. A study using a finer grid near Boston with a sensitivity study of model boundary effects is necessary to clarify whether the predicted changes are a result of insufficient spatial resolution, model boundary effects, or are "real".

(15) Evaluation of Dr. Greenberg's Thesis clearly shows that the barriers studied have sufficient potential impact on water levels to be a serious cause of concern to the United States should a project be seriously considered.

(16) The regional and national importance of a large tidal power station on valuable energy resources as well as its potential physical impact on the entire New England coastline make it absolutely essential to develop and expeditiously pursue a study plan which will quantify potential oceanographic, coastal and environmental impacts.

(17) The only known rational method of quantifying these potential impacts with a reasonable probability of success is by numerical modelling to include the entire New England/Nova Scotia continental shelf and coastline. This numerical oceanographic model must be three dimensional over the entire study area, and be implicit in the computation of surface elevations that would affect land flooding.

(18) The Corps Coastal Engineering Research Center of the Waterways Experiment Station (WES) has a numerical model developed and sufficiently well calibrated and verified to produce with confidence the applicability to this important problem. A three dimensional model developed under work unit No. 31675 by Dr. Peter Sheng, Aeronautical Research Associates of Princeton (ARAP) would be applied to this problem. The application will be a joint fully integrated undertaking by WES and ARAP. Additional field and office studies of chemical and biological oceanographic parameters may also be used.

(19) A prototype data acquisition effort is necessary to quantify the amplitude, phase, and volume transport of tidal constituents at the proposed numerical model boundaries. It may also be necessary to conduct a field study to quantify effects of the existing soon to be operated pilot tidal power station across the Annapolis River at Annapolis Royal, Nova Scotia.

A Phase 1 investigation is strongly recommended to first verify the magnitude of tidal variations. It would utilize a two dimensional numerical model simultaneously. The Corps would develop a comprehensive Study Plan to include a scope of work, and time and cost estimates which would provide a sound basis for Phase 2 effort considered necessary for decisions regarding the impacts of tidal power stations on oceanograhic, coastal and environmental parameters. Phase 2 would include three dimensional mathematical and environmental modelling as well as physical modelling. Eminent experts and consultants would assist in the review of the Study Plan and technical approaches to be used to evaluate this important action. The Corps would work closely with Dr. Greenberg as well as solicit his expertise and experience.

The Corps of Engineers, New England Division (NED), would provide for the overall management, coordination and public involvement, as well as the accomplishment and reporting of the results of the Phase 1 effort. Several independent scopes of work for contracting out separate investigations by Federal, State and local agencies and private organizations as part of Phase 1 efforts will be needed to develop Phase 2 work. Each contract to include an inventory of resources in a field of expertise likely to be impacted, as well as a description of how Phase 2 studies should proceed together with their costs and designated impacts, suggest potential impacts, and their mitigation where required. Technical assistance on tidal hydraulics, as may be necessary, would be provided by NED. NED would also document Phase 2 scopes of work together with costs for those Federal, state and private navigation, flood control and beach projects, along the coast and inland reaches to be affected. NED's legal counsel and real estate division would also investigate international agreements, damages to public and private lands, damage mitigation, and other institutional concerns. Phase 1 to be a two year effort is estimated to cost as follows:

NED COST

- Management, coordination, public involvement to include appropriate uses of State of Maine's Bigelow Lab for review.	$230,000
- Award contracts to inventory specific resources and develop Phase 2 scopes and costs.	$160,000
- Provide technical assistance on tidal hydraulics, and coordinate w/WES to scope out and estimate costs of Phase 2 effort.	$ 45,000
- Inventory coastal projects, develop damage methodology and Phase 2 scope and costs.	$100,000
- Investigate environmental and socioeconomic impacts and develop Phase 2 scope and costs.	$100,000
- Investigate international concerns, damages to public and private lands, and damage mitigation and develop Phase 2 scopes and costs.	$155,000
NED TOTAL	$790,000

The Corps Waterways Experiment Station (WES) will require about 12 months to accomplish its tasks. Concurrently, WES would develop the Phase 2 scope of work and estimate costs to accomplish the three dimensional mathematical and environmental modelling as well as physical modelling.

WES COST

- Phase 1 numerical modelling	$250,000
- Develop Plan of Study for Phase 2	$ 60,000
WES TOTAL	$310,000

SUMMARY OF COSTS

NED COST	$790,000
WES COST	$310,000
PHASE 1 TOTAL COST	$1,100,000

Should you have any additional questions, please call me at (617) 647-8220, or Mr. Joseph L. Ignazio my Chief of Planning who can be reached at (617) 647-8599.

Sincerely,

Carl B. Sciple
Colonel, Corps of Engineers
Division Engineer

Copy Furnished:
Honorable George J. Mitchell
U.S. Senator
151 Forest Avenue
Portland, Maine 04101